Project Title: Contemporary knowledge regarding the potential effects of tall structures on sage-grouse (*Centrocercus* spp.) and other wildlife in the Western United States

Project Purpose

This project will assess the adequacy of existing information to predict and mitigate the potential impacts of tall structures on sage-grouse by identifying information needs, and prioritization of the research needed to provide new knowledge for policy development. The project combines a public input process (stakeholder workshops) with a synthesis of published and unpublished information. This project will result in the publication of a comprehensive document that summarizes contemporary knowledge and policy regarding the effects of tall structures on sage-grouse. This document will also identity and prioritize research needed to fill information gaps and mitigate existing inconsistencies in terms of contemporary policies governing tall structure siting requirements.

<u>Tall Structures</u>: Include power poles, electric transmission lines, wind turbines and associated structures.

Objectives:

1. Synthesis of existing information (published and unpublished) regarding the predicted and potential effects of tall structures on sage-grouse (*Centrocercus* spp.) and other selected wildlife.
2. Synthesis of existing policies regarding siting and other requirements to mitigate the potential effects of tall structures on sage-grouse

Methodology

Synthesis Documents

Development of the preliminary and final synthesis review documents will be completed by Terry Messmer, Quinney Professor for Wildlife Conflict Management, Department of Wildland Resources at Utah State University. The final synthesis will be a compilation of existing Information and the state of contemporary knowledge regarding the potential impacts and mitigation of the effects of tall structures on sage-grouse and other selected wildlife. The synthesis will include a comprehensive search of published and unpublished literature, the worldwide web, personal interviews with state, regional and national sage-grouse experts involved in ongoing research, workshop participants, and a review of state and federal agency policies related to tall structures siting and mitigation requirements.

The final document will also identify the gaps in knowledge required to identify mutually acceptable Best Management Practices for the placement of tall structures and the next steps, including research to address these knowledge gaps. The work product produced by the study shall consist of a written and on-line accessible and searchable document.

Effects of Tall Structures on Sage-grouse and other Avian Species: A Literature Synthesis Documentation (22 July 2010)

Project Title: Contemporary knowledge of the potential effects of tall structures on sage-grouse and other wildlife in the Western United States

Organization: This document was prepared to provide a common information base for workshop participants regarding the potential effects and mitigation of tall structures on sage-grouse and other selected wildlife. This document was compiled over several weeks through library and web-based searches. Keywords searched included the following terms or combinations thereof; power poles, electric transmission lines, utility lines, wind turbines, wind energy, wildlife, sage-grouse, policy, siting requirements, renewable energy, sagebrush, environment, and structures. The search included published and unpublished information and state and federal policies regarding siting and mitigation requirements.

Literature Review

For the literature review, the information has been sorted as follows:

1. Major categories of tall structures

    a. Power and Utility Poles/Transmission Lines
    b. Wind Turbines Structure
    c. General Energy Development

2. Sub-categories

    a. Avian (this has been sub-divided by major species)
    b. Mammals
    c. Infrastructure

3. Topics

    a. Direct Effects – Mortality, mitigation, etc
    b. Indirect Effects - Habitat Use/Environmental Concerns
    c. Potential Benefits
    d. Trade-offs

Within each topical area the information sources were classified by article type to include:

a. Peer-Reviewed Journal
b. Thesis or Dissertation
c. Technical Report
d. Proceedings

Major Category: Power and Utility Poles/Transmission Lines

Sub-category: Avian – Raptors (and multiple species)

Topic: Direct Effects (Mortality – electrocution and birdstrikes – Predation Risks, Mitigation)

Article Type: Peer-Reviewed

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Bevanger, K. 2008. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation 86:67-76.

Abstract: Empirical data and theoretical considerations indicate that species with high wing loading and low aspect run a high risk of colliding with power lines. These birds are characterised by rapid flight, and the combination of heavy body and small wings restricts swift reactions to unexpected obstacles. When the number of reported collision victims is considered relative to the abundance and population size of the species concerned, some Galliformes, Gruiformes, Pelecaniformes and Ciconiiformes species seem to appear in disproportionately high numbers. In contrast, species frequently affected by electrocution particularly seems to involve Ciconiiformes, Falconiformes, Strigiformes and Passeriformes. An alarmingly large number of species with endangered and vulnerable status are identified among the victims, but there are insufficient data at present for judging the significance of mortality caused by power lines at the population level.

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Janss, G.F.E. 2000. Avian mortality from power lines: a morphologic approach of a species-specific mortality. Biological Conservation 95:353-359.

Abstract: Avian mortality from power lines is a species-specific mortality which affects several vulnerable and endangered species. Identifying the characteristics of species at risk of power line mortality can help solve this conservation problem. The relative abundance of bird species near power lines was compared with records of electrocution and collision casualties from these power lines to identify species-specific death risk as determined by wing morphology. Generally, collision victims were "poor" fliers, while electrocution victims were birds of prey, ravens and thermal soarers. Bird species were categorised by wing morphology and risk of either collision or electrocution. Three categories were identified: species with a high risk of collision, species with a high risk of electrocution and a third mixed group, susceptible to both these causes of death. The variables, weight, wing length, total length and tail length classified 88.6% of the species correctly in these three categories when used in a discriminant analysis. The classification can be used in a predictive model to identify species susceptible to power line mortality. The third mixed group warrants special attention from a conservation point of view because risk is not easily identified and depends on specific behaviour and local circumstances.

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Lehman, R.N. 2001. Raptor Electrocution on Power Lines: Current Issues and Outlook. Wildlife Society Bulletin 29:804-813.

Abstract: Electrocution on power lines is one of many human-caused mortality factors that affect raptors. Cost-effective and relatively simple raptor-safe standards for power line modification and construction have been available for over 25 years. During the 1970s and early 1980s, electric industry efforts to reduce raptor electrocutions were very coordinated and proactive, but predictions about resolving the problem were overly optimistic. Today, raptors continue to be electrocuted, possibly in large numbers. The electrocution problem has not been resolved, partly because of the sheer number of potentially lethal power poles in use and partly because electrocution risks may be more pervasive and sometimes less conspicuous than once believed. Also, responses to the problem by individual utilities have not been uniform, and deregulation of the electric industry during the 1990s may have deflected attention from electrocution issues. To control raptor electrocutions in the future, the industry must increase information sharing and technology transfer, increase efforts to retrofit lethal power poles, and above

all ensure that every new and replacement line constructed incorporates raptor-safe standards at all phases of development. Finally, responsibility for the electrocution problem must be shared. Federal, state, and local governments, academic institutions, the conservation community, and the consumer all can play critical roles in an effort that will, by necessity, extend well into the new century.

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Maehr, D.S., A.G. Pratt, and D.K. Voigts. 1983. Bird Casualties at a Central Florida Power Plant. Florida Field Naturalist 11:45-68.

Abstract: Bird mortality at lighthouses, bridges, power lines, radio and TV antennas, tall buildings, and smoke stacks is well documented. Weir (1976) and Avery et al. (1980) thoroughly reviewed bird kills at man-made obstacles, primarily in North America. Bird kills in Florida were summarized for communication towers in Leon County (Stoddard 1962, Stoddard and Norris 1967, Crawford 1974, 1981), Orange County (Kale 1971, Taylor and Anderson 1973, 1974), Ft. Pierce and Tallahassee (Kale 1971). Such losses of birds can provide information about migration patterns and influences of weather on migration. We discuss in this paper two instances of passerine mortality at the Crystal River Generating Facility, Citrus County, Florida.

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James, J.B., E.C. Hellgren, and R.E. Masters. 1999. Effects of Deterrents on Avian Abundance and Nesting Density in Electrical Substations in Oklahoma. Journal of Wildlife Management 63:1009-1017

Abstract: Power outages caused by wildlife at electrical substations can be a major financial burden for utility companies and cooperatives. Snakes, presumably preying on nesting birds, have historically been the major cause of wildlife-related outages at Western Farmers Electric Cooperative (WFEC) substations. We studied avian abundance, diversity, and nesting density, and investigated the efficacy of avian deterrents at 62 substations in the WFEC system in Oklahoma in 1996-97. Data from the first year of the study were consistent with this history: nesting densities and bird abundance were higher at heavily damaged substations (-0.3 incidents/yr) than moderately damaged or undamaged substations. Low-profile substations had more nests, higher bird abundance, and more damage than lattice-design substations. In the second year of the study, we tested 2 bird deterrents: electronic distress calls (noisemakers) and sodium-iodide lights. Neither deterrent was effective at reducing bird nesting or abundance, although noisemakers slightly reduced bird numbers inside the substations relative to the control. We do not recommend noisemakers or sodium iodide light arrays as bird deterrents at electrical substations.

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Janss, G.F.E. and M. Ferrer. 1999. Mitigation of Raptor Electrocution on Steel Power Poles. Wildlife Society Bulletin 27:263-273.

Abstract: Differences exist in electrocution rates of birds on wooden versus metal power poles. However, mitigation measures effective on wooden power poles have not solved electrocution problems on metal poles. We examined the effectiveness of 12 experimental modifications of metal power poles to prevent electrocution of raptors. We did so by comparing raptors' perching behavior on paired modified and control poles. We tested 8 of these modifications in the field by comparing avian mortality before/after modification. Modifications were less effective when a "perch guard" or "perch" was used than when insulation was used. Small raptors (e.g., tawny owl [*Strix aluco*], Eurasian kestrel [*Falco tinnunculus*]) especially were not adequately protected by non-insulation methods. Differences in perching behavior and possibility of electrocution (i.e., wooden vs. steel power poles) caused differences in effectiveness of modifications. We considered insulation of cross arm braces the most effective and practical modification to reduce electrocution of raptors by metal power poles.

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Lammers, W.M. and M.W. Collopy. 2007. Effectiveness of Avian Predator Perch Deterrents on Electric Transmission Lines. Journal of Wildlife Management 71:2752-2758.

Abstract: A new high-voltage transmission line in north-central Nevada, USA, was considered a potential threat to greater sage-grouse (*Centrocercus urophasianus*) because avian predators are attracted to and hunt from elevated perches. As a mitigation measure, perch deterrents were installed on the transmission line towers at the time of construction; in addition, 2 existing high-voltage transmission lines were retrofitted with deterrents. Previous

published studies have investigated the efficacy of perch deterrents in preventing or reducing electrocution of avian predators and fecal contamination of insulators, but none have evaluated deterrents as a means of eradicating perching on towers. We conducted point transect surveys and perching-duration observations of corvids and raptors and determined that although perch deterrents did not prevent perching, the perching duration of raptors on the deterrents was reduced compared to other perching substrates. Perching of raptors indicated that some hunting most likely took place from the towers; therefore, the deterrents did not completely obviate the threat that avian predators posed to greater sage-grouse. Although the deterrents reduced the probability of avian predators perching on the towers, avian predators overcame the deterrents to take advantage of the height of the towers where no other perches of similar height existed. The perch deterrents as designed did not have the desired short-term effect on avian predators, but further monitoring may reveal longer-term effects and distinguish perching behaviors specific to different species of avian predators.

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Prather, P.R. and T.A. Messmer. 2010. Raptor and corvid response to power distribution line perch deterrents in Utah. Journal of Wildlife Management 74:796-800.

Abstract: Increased raptor and corvid abundance has been documented in landscapes fragmented by man-made structures, such as fence posts and power lines. These vertical structures may enhance raptor and corvid foraging and predation efficiency because of increased availability of perch, nesting, and roosting sites. Concomitantly, vertical structures, in particular power distribution lines, have been identified as a threat to sage-grouse (*Centrocercus* spp.) conservation. To mitigate potential impacts of power distribution lines on sage-grouse and other avian species, the electrical power industry has retrofitted support poles with perch deterrents to discourage raptor and corvid use. No published information is available regarding efficacy of contemporary perch deterrents on avian predator use of lower-voltage power distribution lines. We evaluated efficacy of 5 perch deterrents mounted on support poles of an 11-km section of a 12.5-kV distribution line that bisected occupied Gunnison sage-grouse (*Centrocercus minimus*) habitat in southeastern Utah, USA. Perch deterrents were mounted on the line in November–December 2006 following a random replicated block design that included controls. During 168 hours and 84 hours of direct observation in 2007 and 2008, respectively, we recorded 276 and 139 perching events of 7 potential avian predators of sage-grouse. Golden eagles (*Aquila chrysaetos*) were the dominant species we recorded during both years. We did not detect any difference in perching events by perch deterrent we evaluated and controls ($P > 0.05$). Perch deterrents we evaluated were not effective because of inherent design and placement flaws. Additionally, previous pole modifications that mitigated avian electrocutions provided alternative perches. We did not record any raptor or corvid electrocutions or direct predation on Gunnison sage-grouse. The conclusions of this study can be applied by conservation groups and power companies to future management of power distribution lines within areas inhabited by species sensitive to man-made vertical structures.

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Slater, S. J., and J.P. Smith. 2010. Effectiveness of Raptor Perch Deterrents on an Electrical Transmission Line in Southwestern Wyoming. Journal of Wildlife Management 75(5):1080-1088.

Abstract In sagebrush–steppe and other open habitats, power lines can provide perches for raptors and other birds in areas where few natural perches previously existed, with potential negative impacts for nearby prey species, such as greater sage-grouse (Centrocercus urophasianus). Between September 2006 and August 2007, we used driving surveys, behavioral-observation surveys, and prey-remains surveys to assess the ability of perch-deterrent devices to minimize raptor and common raven (Corvus corax) activity on a recently constructed transmission line in southwestern Wyoming. All survey methods demonstrated that activity was significantly lower on the deterrent line compared with a nearby control line; however, deterrent devices did not entirely prevent perching. Considering use of cross-arms or pole-tops alone, we sighted 42 raptors and ravens on the deterrent line and 551 on the control line during 192 driving surveys of each line. Golden eagles (Aquila chrysaetos) and ravens were the species most commonly observed successfully overcoming deterrent devices. Smaller rough-legged hawks (Buteo lagopus) regularly avoided deterrents by perching on conductors (i.e., wires). We documented much off-line activity near both survey lines and suggest that fewer birds near the deterrent line likely reflected reduced availability of nearby alternate perches. There was a pronounced winter peak in on-line perch use, with the effect more evident on the control line. Behavior surveys corroborated our driving-survey results but were otherwise unproductive. During 549 prey-remains surveys of each line, we found 9 single and 60 grouped prey items near deterrent-line poles, compared

with 277 single and 467 grouped items near control-line poles. We observed few sage-grouse in the study area but did witness a likely power line–related, raptor-caused sage-grouse mortality. Overall, our results suggest that perch-deterrent devices can reduce raptor and raven activity\on power-line structures, but to determine their utility on entire power-line segments, we suggest managers consider 1) what level of reduction in perch activity is worth the cost, and 2) the availability of alternate perches in the surrounding landscape.

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Willard, E.D. and B.J. Willard. 1978. The interaction between some human obstacles and birds. Environmental Management 2:331-340.

Abstract: Some of the literature pertinent to the interactions of birds of flight and manmade obstacles, such as transmission lines, is reviewed here. Some birds use these towers, poles, and buildings for nesting and perches. They also collide with them. Original observations presented here suggest that the environmental impacts of these types of obstacles on birds, and vice-versa, seem not due to the inability of the birds to perceive the obstacles, but rather that the birds are apparently distracted from a safe flight pattern by their own species, or by others.

Article Type: Thesis

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Lammers, W.M. 2005. The response of avian predators to a new high voltage transmission line in northern Nevada Master's Thesis, University Of Nevada, Reno. 87 p.

Abstract: Construction of the Falcon to Gonder 345 kV transmission line in Nevada was considered a potential threat to greater sage-grouse because avian predators hunt from towers. Study objectives were to measure the response of local avian predator populations to the new line and to determine the effectiveness of perch deterrents installed on the towers at construction. I conducted point transect surveys before (2003) and after (2004) construction, and perching duration observations of avian predators. I also examined prey remains collected from golden eagle nests, and recorded avian predator visits to monitored greater sage-grouse leks. The abundance and distribution of avian predators did not change significantly in response to the new line. The perch deterrents did not obviate the threat that avian predators posed to greater sage-grouse. Although golden eagles preyed upon greater sage-grouse, predation was considered less of a threat than the harassment by avian predators observed at leks.

Article Type: Technical Report

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Avian Power Line Interaction Committee (APLIC). 2006. Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006. Edison Electric Institute, APLIC, and the California Energy Commission. Washington, D.C. and Sacramento, CA.

Abstract: In the early 1970's, an investigation of reported shootings and poisonings of eagles in Wyoming and other western states led to evidence that eagles were also being electrocuted on power lines. Since then, the utility industry, wildlife resource agencies, conservation groups, and manufacturers of avian protection products and worked together to understand the causes of raptor electrocution and to develop and implement solutions to the problem. Those Efforts have improved our understanding of the biological factors that attract raptors and other birds to power lines, and the circumstances that lead to avian electrocutions. This publication, Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006, summarizes the history and success of over three decades of work. It springs from three previous editions of Suggested Practices for Raptor Protection on Power Lines, and has been expanded and updated to assist those concerned with complying with federal laws, protecting and enhancing avian populations, and maintaining the reliability of electric power networks.

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Erickson, W.P., G.D. Johnson, and D.P. Young Jr. 2005. A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191

We estimate that from 500 million to possibly over 1 billion birds are killed annually in the United States due to anthropogenic sources including collisions with human-made structures such as vehicles, buildings and windows, power lines, communication towers, and wind turbines; electrocutions; oil spills and other contaminants; pesticides; cat predation; and commercial fishing by-catch. Many of the deaths from these sources would be considered unlawful take under federal laws such as the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. In this paper, we summarize this literature and provide the basis for the mortality projections for many of the apparent significant sources. Most of the mortality projections are based on small sample sizes, and on studies typically lacking adjustments for scavenging and searcher efficiency biases. Although the estimates for each source often range by an order of magnitude, the cumulative mortality from all these sources continues to be a concern.

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Lehman, R.N. and Justin S. Barrett. 2000. Raptor Electrocutions and Associated Fire Hazards in the Snake River Birds of Prey National Conservation Area. Report submitted to U.S. Bureau of Land Management and Idaho Power Company, Boise, ID.

Abstract: In 1999, we began an assessment of raptor electrocutions on power lines in and near the Snake River Birds of Prey National Conservation Area (NCA) in southwestern Idaho. The study will allow us to estimate electrocution rates, identify electrocution hazards, and ultimately develop a program to reduce power line-related mortality and fire hazards in the NCA. This year, we produced a distribution line map of the study area, selected study segments, and began searching for dead raptors along 19 segments totaling 61.2 linear km. Study segments are located in the relatively undeveloped interior of the NCA, and along the borders and private inholdings of the NCA where agriculture and associated power line developments are common. From September-November, we visited all study segments to remove remains of birds killed prior to this study. We found partially intact skeletons, scattered bones, and feathers of at least 19 birds during these searches. In December, we began sampling for recent kills and found five dead birds. Of the 24 birds found during both surveys, we were able to identify 6 common ravens (*Corvus corax*), 2 red-tailed hawks (*Buteo jamaicensis*), 2 American kestrels (*Falco sparverius*), 1 northern harrier (*Circus cyaneus*), 1 golden eagle (*Aquila chrysaetos*), and 1 barn owl (*Tyto alba*). Only the golden eagle showed clear signs of electrocution, but most remains were too old to establish cause of death. All 24 sets of remains were found under 21 poles. We found dead birds under 18 tangent poles and 3 poles in deadend and corner positions. Pole-top configurations included simple crossarm, underbuilt, compact, and H-frame designs. Additional hardware items on many poles included exposed jumper wires, transformers, capacitors, and electrical switches of several kinds. In 2000, we will continue sampling study segments each month until a full year of sampling has been completed. This will allow detection of seasonal differences in electrocution rates during three raptor concentration periods--nesting, postfledging, and wintering.

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Manville, A.M., II. 2005. Bird strikes and electrocutions at power lines, communication towers, and wind turbines: state of the art and state of the science – next steps toward mitigation. Pp. 1051-1064. *In:* C.J. Ralph and T. D. Rich (editors) Bird Conservation Implementation in the Americas: Proceedings 3rd International Partners in Flight Conference 2002. U.S.D.A. Forest Service General Technical Report PSW-GTR-191, Pacific Southwest Research Station, Albany, CA.

Abstract: Migratory birds suffer considerable human-caused mortality from structures built to provide public services and amenities. Three such entities are increasing nationwide: communication towers, power lines, and wind turbines. Communication towers have been growing at an exponential rate over at least the past 6 years. The U.S. Fish and Wildlife Service is especially concerned about growing impacts to some 836 species of migratory birds currently protected under the Migratory Bird Treaty Act of 1918, as amended. While mortality estimates are often sketchy, and won=t be verified until nationwide cumulative impact studies are conducted, current figures are troubling. Communication towers may kill from 4-50 million birds per year. Collisions with power transmission and distribution lines may kill anywhere from hundreds of thousands to 175 million birds annually, and power lines electrocute tens to hundreds of thousands more birds annually, but these utilities are poorly monitored for both strikes and electrocutions. More than 15,000 wind turbines may kill 40,000 or more birds annually nationwide, the majority in California. This paper will address the commonalities of bird impacts among these industries; those bird species that tend to be most affected; and research (completed, current, and proposed) intended to reduce bird collisions and electrocutions nationwide. The issues of structure location (siting), lighting, guy supports, lattice or

tubular structures, bird behavior, and habitat modifications are reviewed. In addition, this paper reviews the respective roles and publications of the Avian Power Line Interaction Committee and the Wildlife Workgroup of the NationalWind Coordinating Committee, the roles of the Service-chaired Communication Tower Working Group and Wind Turbine Siting Working Group, and the Fish and Wildlife Services= voluntary communication tower, and turbine siting and placement guidelines. An update on recent Communication Tower Working Group research initiatives will also be discussed along with promising research findings and needs.

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Slater, S.J. and J.P. Smith. 2008. Effectiveness of Raptor Perch Deterrents on an Electrical Transmission Line in Southwestern Wyoming. Report prepared by HawkWatch International Inc. (Salt Lake City, UT) for U.S. Department of Interior.

Abstract: In sagebrush-steppe and other open habitats, electrical distribution and transmission lines (i.e. "power" lines) can provide perches for raptors and Common Ravens (*Corvus corax*) in areas where few natural perches of similar height previously existed. As a result, these manmade perches may indirectly impart negative impacts to potential, nearby prey species, such as the Greater Sage-grouse (*Centrocercus europhasianus*). Between September 2006 and August 2007, we used driving surveys, behavioral-observation surveys, and prey-remains surveys to assess the ability of perch-deterrent devices to minimize raptor and raven activity on recently constructed power line in southwestern Wyoming. All survey types clearly demonstrated that raptor and raven activity were significantly lower on the "deterrent" line compared to a nearby "control" line (i.e., no deterrent devices); however, perching was not entirely prevented. Considering use of cross-arms or pole-tops (i.e., the structures fitted with deterrent devices) alone, we sighted 42 raptors and ravens on the deterrent line and 551 on the control line during 192 driving surveys of each line. Golden Eagles (*Aquila chrysaetos*) and ravens were the species most commonly observed successfully overcoming the deterrent devices. Smaller Rough-legged Hawks (*Buteo lagopus*) regularly avoided the deterrents altogether by perching on the conductors (i.e. wires) themselves. We documented much off-line, alternate perch use (primarily of other, nearby power lines) and flights near both survey lines, but fewer birds were seen off-line near the deterrent line. There was a pronounced winter peak in on-line perch use and off-line activity near both survey lines, but the effect was more dramatic on the control line. Measured perch, vegetation and landscape variables had only a limited ability to protect usage of individual control-line poles. Behavioral-observation survey proved to be largely unproductive, as we recorded only 31 deterrent-line and 124 control-line perch-related behaviors during 192 hours of observation of each line. We found 17 single prey items and 65 grouped items (i.e., pellets or bone clusters) near deterrent-line poles, compared to 398 single prey items and 493 grouped items near control-line poles during 576 prey-remains surveys of each line. During the study, we also witnessed the construction of a Common Raven next between deterrent devices and found 3 Ferruginous Hawk (*Buteo regalis*) ground nests below the control line, one of which fledged four young. Adults and young of both species made extensive use of nearby power-line perches throughout the nesting season. Very few sage-grouse were observed in the study area, but we did document two Greater Sage-grouse mortalities, one likely avian-caused and the other the result of an apparent conductor collision. Overall, our results suggest that perch-deterrent devices can reduce raptor and raven activity on power-line structures. When determining the appropriateness of deterrent devices as a tool to manage raptor and raven perching over entire power-line segments, we suggest managers consider what level of reduction in perching activity is deemed worth the cost, as well as the availability of alternate perches in the surrounding landscape.

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York, R. 2006. Report to PIER Energy-Related Environmental Research, 1516 Ninth Street, Sacramento, California 95814-5512. www.energy.ca.gov/reports/2002-01-10_600-00-030.PDF.

Abstract: The purpose of this project was to analyze products that reduce or prevent wildlife interactions, and resulting electrocutions and power outages, with powerlines and power facilities. Distribution line add-on insulation and perch deterrent products that were added to distribution line power poles were analyzed to evaluate their durability and effectiveness. This research project also evaluated the applicability and effectiveness of a geographic information system (GIS) model that would allow Pacific Gas and Electric (PG&E) to plan future electrical facility upgrades to reduce wildlife electrocutions and associated power outages. The GIS model is designed so it can also help predict "high risk" areas, so that new distribution lines and existing distribution line upgrades can be designed to minimize wildlife electrocution related power outages. The GIS model was also developed in response to a 1994 settlement agreement between PG&E and the U. S. Fish and Wildlife service that arose after citations were issued to

PG&E for the electrocutions of several Swainson's hawks—a State-protected species. Birds and other animals are the fourth leading cause of electric distribution outages in the PG&E system.

Article Type: Proceedings

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Manville, A.M., II. 2009. Towers, turbines, power lines, and buildings – steps being taken by the U.S. Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. *In* C.J. Ralph and T.D. Rich (editors). Proceedings 4th International Partners in Flight Conference, February 2008, McAllen, TX.

Abstract: As imperiled bird populations continue to increase, new challenges arise from the effects of growing numbers of communication towers, power lines, commercial wind facilities, and buildings. This paper briefly reviews steps the USFWS is taking to seriously address structural impacts to migratory birds. New findings will be briefly reviewed that address lighting impacts, new challenges facing birds from tower radiation, and collision and habitat fragmentation effects on avifauna. See the paper in this volume by Klem on his ongoing research with building glass, lighting and windows for details in trying to resolve those challenges.

Sub-category: Avian – Cranes

Topic: Direct Effects - Mortality and Mitigation

Article Type: Peer-Reviewed

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Sundar, K.S.G. and B.C. Choudhury. 2005. Mortality of sarus cranes (*Grus antigone*) due to electricity wires in Uttar Pradesh, India. Environmental Conservation 32:260-269

Abstract: Although overhead electrical wires are known to have caused severe declines of bird populations, there are no studies in India that address this danger, even for endangered species. Rates of mortality, factors affecting mortality and population effects of electrical wires on the globally endangered sarus crane (Grus antigone) were assessed for breeding and non-breeding cranes in Etawah and Mainpuri districts, Uttar Pradesh, India. Non-breeding cranes were most susceptible to wires and, within territories, mortalities were higher for pre-dispersed young. Similar proportions of non-breeding and breeding cranes were killed, together accounting for nearly 1% of the total sarus crane population annually. Supply wires accounted for the majority of sarus crane deaths, and only non-breeding cranes were killed by both supply and high-tension power lines. Non-breeding crane deaths at roost sites were correlated with numbers of roosting birds and numbers of wires at each site. Over 40% of 251 known sarus crane territories had at least one overhead wire posing a risk to breeding adults and pre-dispersed young. A risk index for wires over territories of cranes was computed; mortality was not affected by increasing the number and therefore risk posed by wires. Most crane deaths in territories occurred as a result of wires at edges of territories. Wires around roosting sites, territoriality and age of sarus cranes appear to be the most important factors affecting their mortality due to wires. Mitigation measures will be most effective around roost sites and for wires that border territories of breeding pairs.

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Morkill, A.E. and S.H. Anderson. 1991. Effectiveness of Marking Powerlines to Reduce Sandhill Crane Collisions. Wildlife Society Bulletin 19:442-449.

Abstract: The principal known cause of death for wild fledged whooping cranes (*Grus americana*) is collision with powerlines (Lingle 1987). Such mortality affects the recovery of this federally endangered species (Howe 1989). Collisions with powerlines have to date accounted for 25% of known losses in the Aransas-Wood Buffalo flock (J. C. Lewis, U.S. Fish and Wildlife Service, Albuquerque, N.M., unpubl. data) and 40% in the Rocky Mountain cross-fostered flock (Brown et al. 1987). These data illustrate the need for methods to minimize such losses (U.S. Fish and Wildlife Service 1986, Howe 1989). Sandhill cranes (*Grus canadensis*), a related species, also suffer appreciable

mortality from colliding with powerlines and provide opportunities for studying this problem. Collisions occur mainly during migration, when cranes rest and feed in habitats bisected by powerlines (Tacha et al. 1979, Krapu et al. 1984, Kuyt 1987, Windingstad 1988). Nonconducting static wires usually installed above conductor wires to intercept lightning strikes and prevent power outages are generally smaller in diameter than conductor wires; consequently, birds often see and avoid conductor wires only to strike the less visible static wires (Brown et al. 1987, Faanes 1987). The effectiveness of various methods used to minimize bird collisions with powerlines has not been evaluated critically. A review of the literature indicated that increasing the visibility of powerlines by installing markers on the static wires was the most cost-effective and logistically feasible potential method for reducing bird collisions (Beaulaurier 1981, Archibald 1987). We evaluated the effectiveness of color markers on static wires in reducing sandhill crane collisions with powerlines. We used a yellow aviation ball with a vertical black stripe as a marker.

Sub-category: Avian – Grouse (Galliformes)

Topic: Direct Effects - Mortality and Mitigation

Article Type: Peer-Reviewed

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Aldridge, C. L., And M. S. Boyce. 2007. Linking occurrence and fitness to persistence: habitat based approach for endangered Greater Sage-Grouse. Ecological Applications 17:508–526.

Abstract: Detailed empirical models predicting both species occurrence and fitness across a landscape are necessary to understand processes related to population persistence. Failure to consider both occurrence and fitness may result in incorrect assessments of habitat importance leading to inappropriate management strategies. We took a two-stage approach to identifying critical nesting and brood-rearing habitat for the endangered Greater Sage-Grouse (*Centrocercus urophasianus*) in Alberta at a landscape scale. First, we used logistic regression to develop spatial models predicting the relative probability of use (occurrence) for Sage-Grouse nests and broods. Secondly, we used Cox proportional hazards survival models to identify the most risky habitats across the landscape. We combined these two approaches to identify Sage-Grouse habitats that pose minimal risk of failure (source habitats) and attractive sink habitats that pose increased risk (ecological traps). Our models showed that Sage-Grouse select for heterogeneous patches of moderate sagebrush cover (quadratic relationship) and avoid anthropogenic edge habitat for nesting. Nests were more successful in heterogeneous habitats, but nest success was independent of anthropogenic features. Similarly, broods selected heterogeneous high-productivity habitats with sagebrush while avoiding human developments, cultivated cropland, and high densities of oil wells. Chick mortalities tended to occur in proximity to oil and gas developments and along riparian habitats. For nests and broods, respectively, approximately 10% and 5% of the study area was considered source habitat, whereas 19% and 15% of habitat was attractive sink habitat. Limited source habitats appear to be the main reason for poor nest success (39%) and low chick survival (12%). Our habitat models identify areas of protection priority and areas that require immediate management attention to enhance recruitment to secure the viability of this population. This novel approach to habitat-based population viability modeling has merit for many species of concern.

This paper has been cited by others to substantiate that sage-grouse mortality associated with power lines and roads occurs year-round. This statement is found in the manuscript. “Sage-Grouse may only partially recognize some ecological cues related to anthropogenic features. Birds are run over by vehicles accessing these wells (C. L. Aldridge, unpublished data), and are killed by raptorial predators, such as Golden Eagles (*Aquila chrysaetos*) and Great Horned Owls (*Bubo virginianus*), that perch on the power lines leading to well sites.” The authors provide no documentation or citation to substantiate the statement.

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Beck, J. L., K. P. Reese, J. W. Connelly, and M. B. Lucia. 2006. Movements and Survival of Juvenile Greater Sage-Grouse in Southeastern Idaho. Wildlife Society Bulletin 34:1070-1078.

Abstract: Low recruitment has been suggested as a primary factor contributing to declines in greater sage-grouse (*Centrocercus urophasianus*) populations. We evaluated movements and survival of 58 radiomarked juvenile greater sage-grouse from 1 September (10 weeks of age) to 29 March (40 weeks of age) during 1997–1998 and 1998–1999 in lowland and mountain valley study areas in southeastern Idaho, USA. Juvenile sage-grouse captured in the mountain valley area moved an average of 2.2 km (20%) farther (x =13.0 km, SE =1.2 km) from autumn to winter ranges than juvenile grouse captured in the lowland area (x =10.8 km, SE =1.2 km). Ten of 11 deaths occurred from September to December. Fifty percent of deaths in the lowland population were attributable to human-related mortality including power-line collisions and legal harvest, while 33% and 17% of deaths were attributable to mammalian predators and unknown cause, respectively. All deaths in the mountain valley population were attributed to avian or mammalian predators. Survival was relatively high for birds from both populations, but was higher across years in the lowland (Sˆ = 0.86, SE = 0.06, n¼43) than in the mountain valley population (Sˆ= 0.64, SE = 0.13, n =14). In our study juvenile sage-grouse that moved farther distances to seasonal ranges experienced lower survival than juveniles from a more sedentary population. Moreover, high juvenile survival in our study suggests that if low recruitment occurs in sage-grouse populations it may be due to other factors, especially poor nesting success or low early chick survival.

In their paper the authors discussed mortality by study areas. For Medicine Lodge they reported 5 of 14 (36%) in Medicine Lodge and 6 of 43 (14%) in Table Butte. Two deaths occurred in September (18%), 5 in October (46%), 1 in November (9%), 2 in December (18%), and 1 in March (9%). All mortalities in Medicine Lodge were attributed to natural predators (avian 80%; mammal 20%), while mortality associated with human activities (legal harvest 17%; power-line collisions 33%) accounted for 50% of mortalities in Table Butte. All mortalities associated with human activities in Table Butte occurred during September and October. The remaining deaths in Table Butte were attributable to mammalian predation (33%) and unknown cause (17%). Of total mortalities avian predation was the cause of death for 36% of grouse, followed by mammal predation (27%), power-line collisions (18%), legal harvest (9%), and unknown cause (9%). The powerline mortalities occurred in October. They did not describe the circumstances that may have contributed to the collisions. Increased collisions with overhead wires have been previously has been reported in black grouse in Scotland during the hunting seasons (Miqueta, A. 1990. Mortality in black grouse *Tetrao tetrix* due to elevated cables. Biological Conservation 54:349-355).

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Bevanger, K. and H. Brøseth. 2001. Bird collisions with power lines — an experiment with ptarmigan (*Lagopus* spp.). Biological Conservation 99:341-346

Abstract: The number of ptarmigan (*Lagopus lagopus* and *L. mutus*) killed along three power-line sections through colliding with the overhead wires was recorded over a 6-year period in a subalpine habitat in southern Norway. The effect of an experimental removal of the power-line earth wire (common neutral) was evaluated on one of the power-line sections, by comparing the number of mortalities found before removal with the number found afterwards. The two other power-line sections in the same area were used as control sections. The number of collisions was approximately halved after the lower earth wire was removed, thus confirming the expectation that there is a connection between the number of overhead wire levels (vertically) and the collision rate. The results from this and earlier studies indicate that a reduction in overhead wire levels has a general positive effect by reducing the collision rate. The power companies should develop alternative engineering designs and critically assess constructing power lines with continuous earth wires.

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Bevanger, K. and Brøseth, H. 2004. Impact of power lines on bird mortality in a subalpine area. Animal Biodiversity and Conservation 27: 67–77.

Abstract: Impact of power lines on bird mortality in a subalpine area— Four sections of power lines, amounting to 4,000 km, in a subalpine area of southern Norway were patrolled from April 1989 to June 1995 to record birds killed when colliding with the overhead wires. A total of 399 dead birds and bird remains were identified as collision victims. At least 24 species were identified among the victims, the majority only represented by a few individuals. Ptarmigan (*Lagopus* spp.), particularly Willow ptarmigan (*Lagopus lagopus*), made up 80% of the victims. Season, power–line section and ptarmigan abundance affected the collision rate of this species. The highest rate was found in winter, marginally higher than in spring. Few collided with the power lines in autumn, and none were identified as

victims in summer. On average, the annual minimum ptarmigan collision rate was found to be 5.3 birds km–¹ power line. The only parameter with a predictable effect on the probability of ptarmigan collisions was the height of the trees, as collision spots tended to be in places with low trees. Mortality due to power lines was, on average, at least 2.4 times higher than the annual ptarmigan hunting bag in the area during this 6–year study.

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Knick, S.T., S.E. Hanser, R.F. Miller, D.A. Pyke, M.J. Wisdom, S.P. Finn, E.T. Rinkes, and C. J. Henny. 2010. Ecological influence and pathways of land use in sagebrush. Chapter 13, Studies in Avian Biology. No. 38.

Abstract: The authors described the dominant anthropogenic land uses in the Sage-Grouse Conservation Area (SGCA; the pre-settlement distribution of sage-grouse buffered by 50 km [Connelly et al. 2004, Schroeder et al. 2004]) and their influence on patterns and processes of sagebrush habitats and sage-grouse populations. They considered the primary land uses within the range-wide distribution of Greater Sage-Grouse, which encompasses >2,000,000 km^2 (Connelly et al. 2004). They conducted regional analyses based on seven sage-grouse management zones (Stiver et al. 2006). Sagebrush is the dominant land cover on 530,000 km^2 within the sage-grouse range. They organized land uses into broad categories of agriculture, urbanization and infrastructure, livestock grazing, energy development (nonrenewable and renewable), and military training. The offered the following descriptions regarding the effects of powerlines on sage-grouse and sagebrush habitat. Power lines covered a minimum of 1,089 km^2 and had an ecological influence on almost 50% of all sagebrush within the SGCA. They were not able to map or estimate the density of smaller distribution lines in rural areas. Similar to roads, power lines also followed major river valleys and crossed lower elevations. The Energy Policy Act of 2005 directed that corridors for transporting energy (oil, gas, hydrogen, electricity) be designated on federal land (United States Departments of Energy and the Interior 2008). New corridors, as currently proposed, would affect an additional 2% (12,000 km^2) of the sagebrush across the SGCA currently not influenced by a mapped power line. Amount of additional sagebrush habitat that would be affected by new corridors ranged from <0.2% in the Columbia Basin (13 km^2) and Great Plains (85 km^2), which already have a large proportion influenced by power lines and infrastructure, to >5% in the Northern Great Basin (3,552 km^2). An estimated 9,656 km of overhead power lines have been developed for coalbed methane natural gas production in Powder River Basin (Braun et al. 2002). Over 28,000 km of new roads, 33,000 km of pipelines, and 8,400 km of overhead power lines would be developed as part of the infrastructure to construct an additional 50,000 wells in this 32, 400 km^2 region (United States Department of the Interior 2003c). Similar increased development is planned for other oil and gas producing regions A minimum of 10,182 communications towers >62 m in height were present in the SGCA . The area potentially influenced included 4% of the current sagebrush distribution. They stated that power lines as part of potential cumulative effects of a connecting infrastructure of roads, motorized trails, railways, power lines, and communications corridors fragment or remove sagebrush land cover.

Regarding the potential individual effects of power line on sage-grouse, they stated the following: power line poles along transmission corridors provide nest and perching opportunities for Common Ravens (*Corvus corax*), American Crows (*C. americanus*), and raptors (Reinert 1984, Knight and Kawashima 1993, Steenhof et al. 1993, Lammers and Collopy 2007). Ravens are primary predators on sage-grouse and other prairie grouse nests (Coates et al. 2008, Manzer and Hannon 2005) and can travel >10 km from these locations (Boarman and Heinrich 1999). Collisions with power lines, in addition to increased predation risk, were a primary source of mortality for lowland populations of sage-grouse in Idaho (Beck et al. 2006).

Regarding the effects of wind or geothermal energy they stated the following: the effects of these developments on sagebrush or sage-grouse are largely unknown because development has been too recent to identify immediate or lag effects. Specific environmental concerns of wind turbines were noise produced by the rotor blades, aesthetic (visual), and mortality to bats and birds flying into rotors (United States Government Accounting Office 2005). These considerations may be reduced through advanced technology, but the greater influence on ecosystems is likely to result from roads that are necessary to construct and maintain sites used for wind energy, and power lines that transfer electricity to users (Kuvlesky et al. 2007). Sage-grouse also may avoid areas with turbines because of the visual obstruction (no citation provided). They concluded the energy development physically removes habitat to construct well pads, roads, power lines, and pipelines; indirect effects include habitat fragmentation, soil disturbance, and facilitation of exotic plant and animal spread. More recent development of alternative energy, such as wind and geothermal, creates infrastructure in new regions of the sage-grouse distribution. Land use will continue to be a dominant stressor on sagebrush systems; its individual and cumulative effects will challenge long-term conservation of sage-grouse populations. They author did not cite any specific studies documenting the specific effects of power lines on sage-grouse other than Beck et al. 2006. In this study the authors reported that 2 radio-collared birds were killed by collisions with a power line.

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Johnson, D.J., Holloran, M.J., Connelly, J.W., Hanser, S.E., Amundson, C.L., and Knick, S.T. 2010. Influences of environmental and anthropogenic features on greater sage-grouse populations, 1997-2007. Chapter 17 in Studies in Avian Biology. No. 38.

Abstract. The Greater Sage-Grouse (*Centrocercus urophasianus*) is endemic to western North America and of great conservation interest. Its populations are tracked by spring counts of males at lek sites. We explored the relations between trends of Greater Sage-Grouse lek counts during 1997–2007 and a variety of natural and anthropogenic features. We found that trends were correlated with several habitat features, but not always similarly throughout the range. Lek trends were positively associated with proportion of sagebrush (*Artemisia* spp.) cover, within 5 km and 18 km. Lek trends had negative associations with the coverage of agriculture and exoticplant species. Trends also tended to be lower for leks where a greater proportion of their surrounding landscape had been burned. Few leks were located within 5 km of developed land and trends were lower for those leks with more developed land within 5 km or 18 km. Lek trends were reduced where communication towers were nearby, whereas no effect of power lines was detected. Active oil or natural gas wells and highways, but not secondary roads, were associated with lower trends. Effects of some anthropogenic features may have already been manifested before our study period and thus not have been detected in this analysis. Results of this rangewide analysis complement those from more intensive studies on smaller areas.

The authors stated the following regarding interpretation of the results of their study. A potential bias is that agencies may have discontinued surveys of leks that had become inactive. In that event, inactive leks would tend to have fewer years in which surveys were conducted and would not be included in the analysis if that number of years (during 1997–2007) was less than four, and would be down weighted even if they were included. We investigated the possibility of a discontinuation bias by calculating the percentage of occasions during 1997–2007 for which a zero count was followed by a missing and the percentage of occasions for which a non-zero count was followed by a missing count. If the two percentages are roughly similar, there is no evidence of a discontinuation bias. In fact, non-zero counts were following by missing counts 19 % (4,226/22,517) of the time, whereas zero counts were followed by missing counts 36 % (4,467/12,532) of the time. So the data provide strong evidence of a discontinuation bias: leks on which no sage-grouse were observed in one year were less likely to be surveyed the following year. As an aside, a missing count was followed by another missing count 82 % of the time, indicating a rather low probability that a missing count would be resumed the following year. The net effect of the discontinuation bias is that the data set includes disproportionately fewer abandoned leks than would be representative, and our average lek trend estimates may be biased high.

Our analysis is but a snapshot in time, the time period selected because it had the highest quality data. In many instances, the lek count data we used may not temporally relate to when the anthropogenic stressors examined were added to the landscape. As examples, most of the conversion of fertile soils supporting sagebrush to agriculture occurred during the first half of the 20th century, cheatgrass was well-established throughout much of the Intermountain West by the 1920s, and the majority of paved interstate highways were opened to traffic in the 1960s and 1970s (Connelly et al. 2004). These developments may have caused the extirpation of populations from a region (Aldridge et al. 2008), or leks that remained active may have been isolated from effects of the disturbances (Braun et al. 2002). The results we report here therefore may not accurately reflect the total response of populations to the addition of these factors. A final caveat is that ours is an observational, rather than experimental, study (Shaffer and Johnson 2008). We were not able to assign treatments (reflected by the various explanatory variables: elevation, landscape composition, roads, towers, etc.) in a balanced, random manner. Of the three cornerstones of inference, we lack control and randomization, but have fair to excellent replication both within management zones and among them. One consequence of this is confounding of the explanatory variables, which makes it difficult, at best, to determine which of them is responsible for any effect on the response variable. A more severe consequence is a greater risk incurred by presuming that associations observed in the data reflect causation.

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Miqueta, A. 1990. Mortality in black grouse *Tetrao tetrix* due to elevated cables. Biological Conservation 54:349-355.

Abstract: Black grouse deaths through collisions with cables were studied at ski resorts. Though largely ignored, this mortality is important relative to population numbers. As it is not selective, it could be a direct threat to grouse populations. The inconspicuousness of wires combined with interference to the birds' habits, and human disturbance, are the main factors causing accidents. Collisions are far more frequent on ski-tows and electricity lines than on chairlifts. Recommendations are given.

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Naugle, D. E., K. E. Doherty, B. L. Walker, J. Holloran, and H. E. Copeland. 2010. Energy Development and Greater Sage-Grouse. Chapter 21. Studies in Avian Biology. No. 38.

Abstract: Rapidly expanding energy development in western North America poses a major new challenge for conservation of Greater Sage-Grouse (*Centrocercus urophasianus*). We reviewed the scientific literature documenting biological responses of sage-grouse to development, quantified changes in landscape features detrimental to sage-grouse that result from development, examined the potential for landscape-level expansion of energy development within sage-grouse range, and outlined recommended landscape-scale conservation strategies. Shrublands developed for energy production contained twice as many roads and power lines, and where ranching, energy development, and tillage agriculture coincided, human features were so dense that every 1 km2 could be bounded by a road and bisected by a power line. Sage-grouse respond negatively to three different types of development and conventional densities of oil and gas wells far exceed the species' threshold of tolerance. These patterns were consistent among studies regardless of whether they examined lek dynamics or demographic rates of specific cohorts within populations. Severity of current and projected impacts indicates the need to shift from local to landscape conservation. The immediate need is for planning tools that overlay the best remaining areas for sage-grouse with the extent of current and anticipated development. This will allow stakeholders to consider a hierarchy of set-aside areas, lease consolidations, and more effective best-management practices as creative solutions to reduce losses. Multiple stressors including energy development must be managed collectively to maintain sage-grouse populations over time in priority landscapes.

Regarding the effects of power poles and related infrastructures on sage-grouse the authers state the following: Males and females may abandon leks if repeatedly disturbed by raptors perching on power lines near leks (Ellis 1984), by vehicle traffic on nearby roads (Lyon and Anderson 2003), or by noise and human activity associated with energy development (Braun et al. 2002, Holloran 2005, Kaiser 2006). Collisions with power lines and vehicles, and increased predation by raptors may also increase mortality of birds at leks (Connelly et al. 2000, Lammers and Collopy 2007). Roads and power lines may also indirectly affect lek persistence by altering productivity of local populations or survival at other times of the year. Sage-grouse mortality associated with power lines and roads occurs year-round (Aldridge and Boyce 2007).

In their study on rangelands with energy development contained twice the density of roads (1.57 vs. 3.13 km/km^2) and powerlines (0.27 vs. 0.58 km/km^2) and five times as many ponds (0.12 vs. 0.62 per km^2) as those where ranching was the primary land use. Human features had the highest density where ranching, tillage agriculture, and energy development coincided. At this intensity of land use,70% of the landscape was within 100 m and 85% was within 200 m of a human feature, and densities were sufficiently high that every 1 km^2 of land could be bounded by a road (4.10 km/km^2) and bisected by a power line (0.86 km/km^2).

They conclude the scientific evidence from 1998 to the present that energy development is impacting sage-grouse populations has become apparent. However, questions remain concerning the exact mechanisms responsible for population declines, and manipulative experiments are needed to test the efficacy of mitigation policies and practices. Burying power lines (Connelly et al. 2000), minimizing road and well pad construction, vehicle traffic, and industrial noise (Lyon and Anderson 2003, Holloran 2005), and managing produced water to prevent the spread of West Nile virus (Zou et al. 2006, Walker et al. 2007b) may reduce impacts. Rigorous testing is needed to know whether these or other modifications will allow sage-grouse to persist in developed areas.

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Wisdom, M.J., C.W. Meinke, S.T. Knick, and M.A. Schroeder. 2010. Factors Associated with extirpation of sage-grouse. Chapter 19 in Studies in Avian Biology No. 38.

Abstract. Geographic ranges of Greater Sage-Grouse (*Centrocercus urophasianus*) and Gunnison Sage-Grouse (*Centrocercus minimus*) have contracted across large areas in response to habitat loss and detrimental land uses. However, quantitative analyses of the environmental factors most closely associated with range contraction have been lacking, results of which could be highly relevant to conservation planning. Consequently, we analyzed differences in 22 environmental variables between areas of former range (extirpated range), and areas still occupied by the two species (occupied range). Fifteen of the 22 variables, representing a broad spectrum of biotic, abiotic, and anthropogenic conditions, had mean values that were significantly different between extirpated and occupied ranges. Best discrimination between extirpated and occupied ranges, using discriminant function analysis (DFA), was provided by 5 of these variables: sagebrush (*Artemisia* spp.) area; elevation; distance to transmission lines; distance to cellular towers; and land ownership. A DFA model containing these 5 variables correctly classified >80% of sage-grouse historical locations to extirpated and occupied ranges. We used this model to estimate the similarity between areas of occupied range with areas where extirpation has occurred. Areas currently occupied by sage-grouse, but with high similarity to extirpated range, may not support persistent populations. Model estimates showed that areas of highest similarity were concentrated in the smallest, disjunct portions of occupied range and along range peripheries. Large areas in the eastern portion of occupied range also had high similarity with extirpated range. By contrast, areas of lowest similarity with extirpated range were concentrated in the largest, most contiguous portions of occupied range that dominate Oregon, Idaho, Nevada, and western Wyoming. Our results have direct relevance to conservation planning.

The authors concluded identifying which environmental factors are operating in a cause-effect manner in relation to extirpation and which may simply be correlative, is a challenge not easily addressed except through consideration of our results in relation to the larger body of sage-grouse literature. Our results confirm prior research documenting sage-grouse as a species whose persistence depends on adequate areas of sagebrush. This inference extends to other sagebrush variables--patch size, proximity among patches, and size of core areas—that also were associated with extirpation. These results illustrate the strong effect of sagebrush abundance and distribution on sage-grouse persistence; without large areas of contiguous sagebrush, sage-grouse cannot persist. A cause-effect relationship of anthropogenic variables such as area in agriculture, human density, road density, and distance to highways is indicated by past research documenting the widespread conversion of sagebrush habitat to these land uses (Braun 1998; Vander Haegen et al.2000; Knick et al. 2010); by the facilitation of exotic plant invasions into sagebrush habitats adjacent to these land uses (Hann et al. 1997), especially adjacent to roads (Gelbard and Belnap 2003); and by mortality of sage-grouse along roads and highways (Lyon and Anderson 2003, Aldridge and Boyce 2007). The strong associations of elevation and land ownership with sage-grouse extirpation represent the widespread conversion of low-elevation, private lands to non-sagebrush land uses, such as agricultural and urban developments (Vander Haegen et al. 2000; Knick et al. 2010), as well as the substantial loss of sagebrush from widespread exotic plant invasions at lower elevations (Hann et al. 1997; Meinke et al. 2008). In that context, elevation and land ownership are ideal indicators of underlying causes of extirpation. Finally, two variables strongly associated with sage-grouse extirpation, distance to transmission lines and distance to cellular towers, have unknown relations with sage-grouse population dynamics at regional extents. New, mechanistic research is needed to understand the potential relation between these variables and sage-grouse extirpation.

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Wolfe, D.H., M.A. Patten, E. Shochat, C.L. Pruett, and S.K. Sherrod. 2007. Causes and Patterns of Mortality in Lesser Prairie-chickens *Tympanuchus pallidicinctus,* and Implications for Management. Wildlife Biology 13(sp1):95-104.

Abstract: Life-history studies of prairie grouse have focused on reproductive ecology, habitat use, movement patterns and survivorship, with only cursory or anecdotal references to mortality causes, or they have been of insufficient duration or scale to infer mortality patterns. Because mortality causes and patterns affect other life-history traits, their determination adds to our overall understanding of grouse demographics. As part of a long-term study on lesser prairie-chicken *Tympanuchus pallidicinctus* natural history in Oklahoma and New Mexico, we

recovered 322 carcasses of radio-tagged birds captured on leks. We were able to determine the cause of death for 260 of these birds. Predation by raptors accounted for the largest number of mortalities (91), followed by collisions with fences (86), predation by mammals (76), collisions with power lines (4), and collisions with automobiles (3). Mortality causes differed considerably between study sites and between sexes, with all collisions more frequent in Oklahoma than in New Mexico, in females than in males, and in older than in young females. Although predation is a major cause of mortality, we argue that predator control may not be effective for grouse conservation. Moreover, in cases where top predators reduce mesopredator population densities, for example those of red foxes *Vulpes vulpes*, indiscriminate removal of predators may hasten the decline of grouse populations. Land managers striving to conserve prairie-chickens and other grouse species should attempt to reduce or eliminate collision mortality risks in addition to efforts to improve nesting or brood-rearing habitat. Collision risks should also be evaluated for potential release sites of translocated or captive-reared grouse.

Article Type: Technical Report

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Atamian, M. and J. Sedinger. 2005. Dynamics of Greater Sage-grouse (*Centrocercus urophasianus*) Populations in Response to Transmission Lines in Central Nevada. Progress Report: Year 3. Department of Natural Resources and Environmental Sciences, University of Nevada - Reno.

Abstract**:** To characterize demographic processes in greater sage-grouse (*Centrocercus urophasianus*), we monitored 11 lek sites in a 3800 km^2 area in Eureka County, Nevada. The long-term goal of this 10 year study is to assess the impact of Sierra Pacific Power Company's Falcon-Gondor transmission line on sage-grouse demography and population dynamics. We used mark-recapture, lek observations, nest & brood monitoring, vegetation sampling and radio telemetry to estimate key demographic parameters. A total of 474 sage-grouse (378 male, 88 female, & 8 young of the year) have been banded with both a color and metal band during the first three years of the study. We used lek observations, and recaptures and resighting of banded individuals to estimate population demography and movement probability. The robust design data structure for capture-recapture data for males made use of the pattern of captures among months of the lekking period and allowed us to estimate size of the male population, annual survival of males and the probability that the average male attended a lek at least once during the spring. We used radio telemetry to locate nesting females, follow broods through fledging, and to estimate female survival. Once located, nests were monitored to estimate nest success and nest site vegetation was measured. Using Program MARK, we estimated daily nest survival at 0.9562 (95% CI = 0.9412-0.9675) and nest success at 0.2853 (95% CI = 0.1823-0.3966). Nest site vegetation characteristics were evaluated as covariates in a nest success analysis. Our data suggested a correlation between nest success and some of these vegetation parameters. Hens with broods were checked once a week and their young counted until young were independent (45-50days). We estimated chick survival for the first 45 days at 0.2987 (95% CI = 0.2168-0.4106). Program MARK known fate data type, was used to estimate an annual female survival of 0.5952 (95% CI = 0.5095-0.6809). We estimated the size of the male population as 684 ± 76 (SE). Annual survival of adult males was estimated as 0.68 ± 0.06. and the probability that the average male attended a lek at least once was 1.0.

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Atamian, M., C. Frey, and J. Sedinger. 2006. Dynamics of Greater Sage-grouse (*Centrocercus urophasianus*) Populations in Response to Transmission Lines in Central Nevada. Progress Report: Year 4. Department of Natural Resources and Environmental Sciences, University of Nevada - Reno. www.ag.unr.edu/sedinger/Progress_Report_2006.doc.

Abstract: To characterize demographic processes in Greater Sage-grouse (*Centrocercus urophasianus*), we monitored 12 lek sites in a 3800 km^2 area in Eureka County, Nevada. The long-term goal of this ten-year study is to assess the impact of Sierra Pacific Power Company's Falcon-Gondor transmission line on sage grouse demography and population dynamics. We used mark-recapture, lek observations, nest & brood monitoring, vegetation sampling, and radio telemetry to estimate key demographic parameters. A total of 679 sage grouse (532 male, 138 female, & 9 unknown sex young of the year) have been banded with both a color and metal band during the first three years of the study. We used lek observations, recaptures, and resighting of banded individuals to estimate demographic parameters and movement probability. We used a robust design structure to analyze capture-recapture data for males (making use of the pattern of captures among months of the lekking period) which allowed us to estimate size

of the male population, annual survival of males and the probability that the average male attended a lek at least once during the spring. We used radio telemetry to locate nesting females, follow broods through fledging, and to estimate female survival. Once located, nests were monitored to estimate nest success, and nest site vegetation was measured after hatch. Nest site vegetation characteristics were evaluated as covariates in a nest success analysis in Program MARK. Our data suggested that nests with 65% total shrub cover have twice the probability of success than nests with 25% (0.29 versus 0.15 respectively). Hens with broods were checked once a week and their young counted until young were independent (45-50 days). We have tagged 184 chicks with Passive Integrated Transponder tags for permanent identification in the last two years of the study. We estimated chick survival for the first 50 days at 0.2329 (95% CI = 0.2059-0.2599) using the Kaplan Meier method of survival estimation. Program MARK known fate data type was used to estimate an annual female survival of 0.5589 (95% CI = 0.4876-0.6303). Our estimates for size of the regional male population ranged from 381 ± 37 (2004) to 472 ± 44 (2006). We estimated annual survival of males = 0.63 ± 0.04. Probability of being present on a lek during the breeding season also did not vary among years or among age classes, although there was modest evidence (sum of model weights for models containing an age effect for $\gamma = 0.4$) that juvenile males (ca. 10 months old) were less likely to be present ($1-\gamma = 0.91 \pm 0.14$) during the entire breeding season than was true for adult males ($1-\gamma > 0.99 \pm < 0.01$).

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Bevanger, K., G. Bartzke, H. Brøseth, J.O. Gjershaug, F. Hanssen, K.-O. Jacobsen, P. Kvaløy, R. May, T. Nygård, H.C. Pedersen, O. Reitan, S. Refsnæs, S. Stokke, and R. Vang. 2009. Optimal design and routing of power lines; ecological, technical and economic perspectives" (OPTIPOL). Progress Report 2009. – NINA Report 504. 46 pp.

Abstract: From 2009 inclusive, NINA has received economic support for research on power lines and wildlife from the Norwegian Research Council (NFR) through the RENERGI Programme. The project is named "*Optimal design and routing of power lines; ecological, technical and eco-nomic perspectives*" (OPTIPOL). It is scheduled for 5 years (2009-1013) and is part of the activities within CEDREN, i.e. the *Centre for environmental design of renewable energy* (cf. http://www.cedren.no). With a grid close to 200 000 km overhead power-lines, the associated rights-of-way (ROW) affect huge land areas in Norway. The overall goal is to develop predicting tools for optimal routing of power lines from an environmental perspective and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation. Thus, the OPTIPOL rationale is based on the belief that the negative effects of electricity transmission and distribution can be reduced with respect to birds and mammals. OPTIPOL has several ambitious objectives, and is divided into sub-projects and specific tasks. From the first of November a PhD-student became part of the project, a position that will be held for 4 years. The main objective of the PhD-activities will be to assess how and why different wildlife species use deforested areas below power lines, evaluate possible positive and negative effects of power-line ROWs, and assess the possibilities for quality improvement. Another part of the project is dedicated the effects of linear structures on movement patterns and distribution in the landscape in native deer species. Here we will examine how different spatial scales influence the processes that guide movement patterns, and responses to linear structures. Another focus will be small game species, with mountain hare, capercaillie, black grouse and hazel grouse as model species. The main objective will be to assess the impact of transforming ROW habitats into attractive small-game foraging habitats. Moreover avoidance behaviour of gallinaceous birds towards power-line corridors will be studied, using capercaillie and hazel grouse as model species. Finally, mortality rates due to power-line collisions, relative to other human-related mortality factors (primarily hunting) among gallinaceous birds will be assessed, using capercaillie and black grouse as model species. Efforts to identify how topographic factors, including vegetation structure, affect bird-collision risk also are part of this work package. A wachtelhund, born in September 2009, is now being trained to locate dead birds in power-line corridors. The efforts to identify species- and site-specific factors regarding bird collisions with power lines is also the rationale behind a subproject where we are developing an online web application for registering dead bird data via Internet. We will target as many relevant users as possible and existing bird-collision data from various projects in NINA will also be imported into the database. A functional prototype of the web application is finished, and incorpo-rates topographical maps, and the possibility of overlaying power-line maps. The work with a Least Cost Path (LCP) toolbox for optimal routing of power lines has started. A pilot LCP-GIS-toolbox has been developed and will be further developed in 2010. Data from the national power-line database from NVE has been organised for internal use in a restricted/classified database at NINA. These data are used together with ecological background data to identify case-study areas. The first stage of the work on power-line colour camouflaging and mitigating measures regarding bird collisions and electrocution are made as reviews studies and will be finalized in 2010.

Guidelines for technical solutions to mitigate bird collisions and electrocution hazard have started and will be an important part of the work in 2010. The eagle-owl is used as a model species in connection to the studies of electrocution mitigating measures. The study includes use of GPS-satellite telemetry to see how the eagle owls use the pylons during hunting activities. This will also give data on eagle-owl movements and electrocution rate. In 2009 3 adult and 4 juvenile eagle owls were equipped with GPS-radio transmitters.

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Comstock, B. and J. Sedinger. 2003. Dynamics of Sage Grouse (*Centrocercus urophasianus*) Populations in Response to Transmission Lines in Central Nevada. Progress Report: Year 1. Department of Natural Resources and Environmental Sciences, University of Nevada - Reno. http://www.ndow.org/wild/conservation/sg/gov/falcon_gonder_report.pdf

Introduction: Sage-grouse populations have been declining in the west over the last four decades (Nevada Sage Grouse Project 2001) although a decline in Nevada's populations is less certain. Sage grouse are an obligate sagebrush species and require this vegetation type for nesting, brood rearing and over-winter habitat (Connelly et al 2000). Habitat loss and degradation are thought to have played a major role in the declines of sage grouse (Nevada Sage grouse project 2001). Transmission lines are hypothesized to restrict birds on leks because they provide sites on which raptors or ravens (*Corvus corax*) may perch (Alstatt 1995). Presence of avian predators in close proximity to leks or nesting areas may directly influence survival or nest success of sage grouse (Hall and Haney 1997). Alternatively, sage grouse may avoid areas where they are exposed to perching avian predators (Hall and Haney 1997). Both mechanisms could affect the dynamics of local populations but may have different implications at the regional scale. Only a single post-hoc study (Hall and Haney 1997) has examined the impact of transmission lines. The study showed generally lower peak lek attendance at leks nearer the transmission line, but the study could not account for confounding factors (that might influence both grouse and transmission lines) nor has it been replicated. The mechanism underlying the relationship detected by Hall and Haney (1997) also has not been determined nor has its consequences for local grouse populations.

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Hall, F. and E. Haney. 1997. Distribution and trend of sage-grouse (*Centrocercus urophasianus*) in relation to overhead transmission lines in northeastern California. California Department of Fish and Game. Unpublished report.

Cited but not found.

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Ellis, K.L. 1985. Effects of a new transmission line on distribution and aerial predation of breeding male sage grouse. Report for Deseret Generation and Transmission Cooperative, Sandy, Utah.

Conclusions and management implications: A number of interesting and useful conclusions can be drawn from this study. The following in a manifestation:
1. Breeding male sage grouse will not tolerate drastic environmental manipulation adjacent to a lek,
2. The placement of transmission line structures in the lane between leks and day use areas will cause an alteration of normal dispersal patterns,
3. The placement of transmission line structures in close proximity to a lek (within 200 m in this case) will cause an increase usage of the structures as hunting sites by raptors in the area,
4. Increased usage of towers adjacent to the lek by raptors will result in increased harassment of lekking grouse,
5. New transmission line routes should avoid leks and/or day use areas by at least 1.2 km and preferably by 1.5 km if breeding activity is to remain undisturbed, and
6. Males are very selective in the choice of day use areas and these areas must be considered as important as the lek site itself when altering an area adjacent to a lek.

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Rocklage, A.M., F.B. Edelmann, and V.R. Pope. 2003. Distribution of Sage and Sharp-tailed Grouse in Hells Canyon and Transmission Line Corridors Associated with the Hells Canyon Complex. Technical Report,

Appendix E.3.2-8, Hells Canyon Complex. Revised July 2003 Idaho Power Company. http://www.idahopower.com/pdfs/Relicensing/hellscanyon/hellspdfs/techappendices/Wildlife/e32_08.pdf

Abstract: The objective of this study was to determine the presence and status of sage grouse (*Centrocercus urophasianus*) and Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) in the Hells Canyon Study Area and within transmission line rights-of-way associated with the Hells Canyon Complex. Within Hells Canyon, sage and sharp-tailed grouse historically occurred only in shrub-steppe habitats adjacent to and immediately upstream of Brownlee Reservoir. Searches, therefore, were restricted to this area, called the Brownlee Reservoir Survey Area, which was divided into 4 Lek Search Units (LSUs): the Oregon Northern and Southern LSUs and the Idaho Northern and Southern LSUs. In April 1996, we conducted lek searches by helicopter in the Brownlee Reservoir Survey Area. We covered approximately 1,230 km2 (475 mi2) of suitable habitat, using 25 hours of helicopter time. In April 1998, we conducted 12 hrs 40 min of helicopter searches within the Transmission Line Survey Area. Search efforts focused on a 0.5-km buffer around approximately 652 km (405 mi) of transmission line rights-of-way. We detected no sage or sharp-tailed grouse leks in either the Brownlee Reservoir or Transmission Line survey areas. We cannot conclude, however, that these species no longer occur in these areas. First of all, incidental observations and historic leks of both grouse species on the study area suggest they are present in low numbers. Second, although searches were conducted to maximize detection of grouse (e.g., early morning hours with good visibility), many factors may have contributed to results. Low population densities, time of day, disturbances, and weather could have influenced detectability of grouse during these surveys. Hence, we recommend multiple surveys within and among years to more accurately determine the presence of sage and sharp-tailed grouse in the Brownlee Reservoir Survey Area and transmission line rights-of-way.

Article Type: Proceedings

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Braun, C.E. 1998. Sage grouse declines in Western North America: What are the problems? Proceedings, Western Association of Fish and Wildlife Agencies 78:139-156.

Abstract: Sage grouse (*Centrocercus urophasianus*) populations have declined throughout western North America. This species has been extirpated in five states and one province, all at the periphery of the original distribution. Breeding population size in each of 3 additional states and two provinces is estimated at less than 2000 individuals. Declines in population size in Colorado have varied from 45 to 82% since 1980, depending upon the area, and the range-wide estimate is at least 30% decrease since 1985. Major factors involved in the documented decreases in distribution and abundance are habitat loss (usually permanent), habitat fragmentation (usually permanent), and habitat degradation (usually short term, 2 to 30 years). No single factor is responsible for the observed declines and human-induced habitat changes are accentuated by periodic drought. No natural undisturbed habitats are known to exist and active management of sagebrush (*Artemisia* spp.) rangelands is needed on a management experiment basis.

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Connelly, J.W. 2005. Prairie grouse and Elevated Structures: An Environmental Planning Challenge. Pages 41-43. *In*: S.S. Schwartz (ed.) Onshore Wildlife Interactions with Wind Developments: Research Meeting V - Proceedings. Landsdowne, VA. http:/www.nationalwind.org/events/wildlife/2004-2/proceedings.pdf

Cited but internet link not available.

Sub-category: Raptors and Ravens

Topic: Indirect Effects - Habitat Use (Predation risks)

Article Type: Peer-reviewed

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Coates, P.S. and D.J. Delehanty. 2010. Nest Predation of Greater Sage-Grouse in Relation to Microhabitat Factors and Predators. Journal of Wildlife Management 74(2):240-248.

Abstract: Nest predation is a natural component of greater sage-grouse (*Centrocercus urophasianus*) reproduction, but changes in nesting habitat and predator communities may adversely affect grouse populations. We used a 2-part approach to investigate sage-grouse nest predation. First, we used information criteria to compare nest survival models that included indices of common raven (*Corvus corax*) abundance with other survival models that consisted of day of incubation, grouse age, and nest microhabitat covariates using measurements from 77 of 87 sage-grouse nests. Second, we used video monitoring at a subsample of 55 of 87 nests to identify predators of depredated nests (n = 16) and evaluated the influence of microhabitat factors on the probability of predation by each predator species. The most parsimonious model for nest survival consisted of an interaction between day of incubation and abundance of common ravens ($w_{raven \times incubation\ day} = 0.67$). An estimated increase in one raven per 10-km transect survey was associated with a 7.4% increase in the odds of nest failure. Nest survival was relatively lower in early stages of incubation, and this effect was strengthened with increased raven numbers. Using video monitoring, we found the probability of raven predation increased with reduced shrub canopy cover. Also, we found differences in shrub canopy cover and understory visual obstruction between nests depredated by ravens and nests depredated by American badgers (*Taxidea taxus*). Increased raven numbers have negative effects on sage-grouse nest survival, especially in areas with relatively low shrub canopy cover. We encourage wildlife managers to reduce interactions between ravens and nesting sage-grouse by managing raven populations and restoring and maintaining shrub canopy cover in sage-grouse nesting areas.

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Harness, R.E. 2005. Raptor Nest Management on Power Lines. In: M.H. Hamza (editor) Proceedings (468) European Power and Energy Systems - 2005. Benalmadena, Spain. 546 pg.

Abstract: Although nesting on power line structures has benefited some raptor species, line operational problems have occurred, and utilities have implemented labor-intensive methods to combat bird nesting on their lines. Historically, methods have typically included direct nest removal and trimming of nesting materials. This approach often has been unsuccessful, and a number of utilities have ultimately concluded that accommodating bird nests is a more sound approach. Managing where raptors nest on utility structures has not only solved many operational problems, but it also has resulted in positive publicity for many line operators. There also are a variety of stick deflectors that can be used to discourage nesting. In distribution construction, engineered single crossarms are preferred over double arms at potential nesting areas. A successful nest management program includes plans to make nearby lines raptor safe from electrocutions. The combination of providing nests with bird-friendly utility configurations can result in electric facilities enhancing wild raptor populations without impacting power reliability.

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Knight, R.L. and J.Y. Kawashima. 1993. Responses of Raven and Red-Tailed Hawk Populations on Linear Right-Of-Ways. Journal of Wildlife Management 7:266-271.

Abstract: Linear right-of-ways are ubiquitous in the United States and may alter vertebrate populations, yet they remain little studied. We examined the relationship between these areas and common raven (*Corvus corax*) and red-tailed hawk (*Buteo jamaicensis*) populations in the Mojave Desert of California by flying helicopter transects along paved highways, transmission powerlines, and control areas (i.e., no highways nor powerlines within 3.2 km). Ravens were equally ($P > 0.10$) common along highway and powerline transects, but were more ($P < 0.02$) abundant along these transects than along controls. Raven nests were more ($P < 0.0001$) abundant along powerlines than along either highways or controls. Red-tailed hawks and their nests were more ($P < 0.0001$) abundant along powerlines than along either highway or control transects. Neither species used potential nest or perch sites in proportion to their availability. Ravens used power poles as nest sites more ($P < 0.001$) than expected based on availability, but not ($P > 0.10$) as perch sites. Red-tailed hawks used power poles for both nesting and perching more ($P < 0.001$) than expected based on availability. Our data suggest that ravens are more abundant along highways because of automobile-generated carrion, whereas both ravens and red-tailed hawks are more common along powerlines because of the presence of superior perch and nest sites. We recommend that land managers evaluate possible changes in vertebrate populations and community-level interactions when assessing the effects of future linear right-of-way projects.

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Steenhof, K., M.N. Kochert, and J.A. Roppe. 1993. Nesting by Raptors and Common Ravens on Electrical Transmission Line Towers. Journal of Wildlife Management 57:271-281.

Abstract: Raptors and common ravens (*Corvus corax*) (hereafter called ravens) began nesting on towers along a 596-km segment of a 500-kV transmission line in southern Idaho and Oregon within 1 year of its construction. We began monitoring these nesting populations in 1981 to assess the effectiveness of artificial structures in attracting nesting raptors and to provide guidelines for enhancing raptor nesting opportunities on transmission lines. Within 10 years, 133 pairs of raptors and ravens were nesting along the 500-kV line. Rapid colonization of towers along the line probably was due to lack of other nesting substrate in the transmission line corridor, and the proximity of existing nesting populations in the nearby Snake River Canyon. Transmission towers provided both new and alternative nesting substrates. Raptors and ravens used all types of towers on the line but preferred (all $P < 0.05$) tower types and sections of towers where steel latticework was relatively dense. They tended to nest on the same or adjacent towers each year even though a low percentage of nests remained intact after the breeding season. Destruction of nests by wind was the most common cause of nest failure on transmission towers. Artificial platforms protected nests from wind damage, and hawks and eagles showed a preference for platforms. Overall nesting success of pairs on transmission towers was similar to or higher than that of pairs nesting on other substrates. Utility companies can enhance raptor nesting opportunities and minimize conflicts with power transmission by providing stable nesting substrate that is not directly above insulators. Nest site modifications either during or after line construction can attract nesting raptors and improve their nesting success.

Subcategory: Bird – General

Topic: Potential Benefits

Article Type: Peer-reviewed

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Yahner, R.H., R.J. Hutnik and S.A. Liscinsky. 2002. Bird Populations Associated with an Electric Transmission Right-of-Way. Journal of Arboriculture 28:123-130.

Abstract: A 2-year study of bird populations was conducted along a 230-kV transmission line right-of-way (ROW) in spring (June) and summer (August) 2000 and 2001. Forty-four species were observed on the ROW during 2000 and 2001. In 1987 and 1988 combined, 39 species were noted on the ROW; thus, bird populations have changed relatively little over the past 13 to 14 years. In both 2000 and 2001, slightly more species occurred on the ROW in summer ($n = 26–32$) than in spring ($n = 25–26$), and considerably fewer species were noted in the adjacent forest in both spring ($n = 8–13$) and summer ($n = 7$). Common bird species (≥50 individuals/100 ha/day) on the ROW were those adapted to brushy or early successional habitat. Most species were found in the low-volume basal spray and foliage spray units ($n = 29$ and 28 species, respectively), and fewest species were noted in the handcutting unit ($n = 19$ species). Considerably more bird species were observed in border zones than in wire zones of the ROW in 2000 and 2001 combined ($n = 39$ versus 17 species, respectively). Moreover, abundance of all bird species combined was nearly fourfold higher in border zones (1,530 individual birds/100 ha/day) than in wire zones (393 birds/100 ha/day). Thus, the border zone is a very important habitat for birds along a ROW, with its combination of shrub–forb–grass cover type.

Article Type: Proceedings

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Weber, D.A. 2004. Winter raptor use of prairie dog towns in the Denver, Colorado vicinity. Pp. 195-199. *In*: Shaw, et al. (eds.) Proceedings of the 4th International Urban Wildlife Symposium.

Abstract: The Denver, Colorado metropolitan area is one of the fastest growing areas in the United States. Rapid development is destroying wildlife habitat, and the Colorado Division of Wildlife (CDOW) is attempting to deal with the situation. A large number of black-tailed prairie dog (*Cynomys ludovicianus*) towns exist around the

urbanized area, but are rapidly being destroyed. CDOW biologists noted that prairie dog towns in the north metro area appeared to be receiving heavy use during the winter months by feeding raptors, mainly bald eagles (*Haliaeetus leucocephalus*), golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and red-tailed hawks (*Buteo jamaicensis*). The CDOW decided to document the winter raptor/prairie dog connection by gathering specific information on raptor use of prairie dog towns. In the winters of 1994 (12 towns), 1995 (15 towns), and 1996 (38 towns) raptor use of selected prairie dog towns was monitored by observers viewing each town for 15-minute intervals. Also recorded was the acreage, number of active burrows, number of available perches and a description of adjacent land uses. Prairie dog towns received high use by hunting raptors all 3 years of the study: 1994 - 6.6 raptors/hour, 1995 - 5.7 raptors/hour, and 1996 - 4.2 raptors/hour. We felt that these levels of use represented very high raptor reliance on prairie dogs. Four species of raptors were most commonly observed: ferruginous hawks 39.1%, red-tailed hawks 22.5%, bald eagles 15.3%, golden eagles 6.4%, and other/unidentified 16.7%. There was high variability in raptor use from one town to the next, ranging from a high of 12.0/hour to a low of 0.5/hour. Three possible reasons for the variable use were investigated: 1) number of prairie dogs in the town; 2) availability of hunting perches; and 3) surrounding land use. Raptor use was closely correlated with the number of active prairie dogs in a town, the more prairie dogs the more raptors. Availability of perch sites appeared to be a positive factor in encouraging raptor use, but the data were not conclusive. The amount of urbanization adjacent to the town did not appear to be correlated with raptor use. Many raptors readily hunted prairie dogs close to heavy urbanization. The CDOW is using this information as the main justification for implementing an initiative to attempt to save or replace prairie dog towns being lost to development as Denver expands.

Subcategory: Infrastructure

Topic: Environmental Trade-off

Article Type: Technical Report

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Bumby, S., K. Druzhinina, R. Feraldi, and D. Werthmann. 2009. Life cycle assessment (LCA) of overhead versus underground primary power distribution systems in Southern California. Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA. http://fiesta.bren.ucsb.edu/~cable/

Project Abstract: High electrical power demand has spurred discussion on the trade-offs between overhead and underground power distribution systems. Many regions in the United States, European Union, and Australia are considering revising the protocol for new power distribution installations and/or conversion of existing infrastructure to underground mode. Studies generally concur that underground distribution is much more costly to install, but may improve reliability and decrease maintenance costs. Recently, a few comparative environmental assessments of overhead and underground cable production have been conducted. However, current literature lacks a full investigation of the life cycle environmental impacts of both distribution methods, including all infrastructure components. This project thus examines the difference between the potential environmental impacts of overhead and underground primary power distribution systems. It is based on a full Life Cycle Assessment (LCA), which has been conducted using LCA software GaBi 4.3, which draws from a wide range of data sources. The analysis incorporates detailed information on the use phase, including installation, maintenance, and decommissioning of cable and associated infrastructural components. The study is also specific to Southern California Edison, one of the largest electric utility suppliers in the United States. The results cover a wide range of environmental concerns, such as climate change, photochemical smog, acidification, and toxicity.

Major Category: **Wind Turbines**

Sub-category: Avian (Multiple)

Topic: Direct Effects - Mortality/Avoidance

Article Type: Peer-reviewed

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Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381-387

Abstract: Wind energy is a rapidly growing sector of the alternative energy industry in North America, and larger, more productive turbines are being installed. However, there are concerns regarding bird and bat fatalities at wind turbines. To assess the influence of turbine size on bird and bat fatalities, we analyzed data from North American wind energy facilities. Diameter of the turbine rotor did not influence the rate of bird or bat fatality. The height of the turbine tower had no effect on bird fatalities per turbine, but bat fatalities increased exponentially with tower height. This suggests that migrating bats fly at lower altitudes than nocturnally migrating birds and that newer, larger turbines are reaching that airspace. Minimizing tower height may help minimize bat fatalities. In addition, while replacing older, smaller turbines with fewer larger ones may reduce bird fatalities per megawatt, it may result in increased numbers of bat fatalities.

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Chamberlain, D.E., M.R. Rehfisch, A.D. Fox, M. Desholm and Sarah J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148:198–202.

The model of Band *et al*. (2005) used data describing the structure and operation of the turbines: number of blades; maximum chord width and pitch angle of blades; rotor diameter; and rotation speed; and of bird size and flight: body length; wingspan; flight speed; flapping; or gliding flight, to derive a probability of collision. This approach was found to be generally sound mathematically (Chamberlain *et al*. 2005). Sensitivity analysis suggested that key parameters in determining collision risk were bird speed, rotor diameter and rotation speed, although variation in collision risk was still small within the likely range of these variables. Mortality is estimated by multiplying the collision probability by the number of birds passing through the area at risk height, determined from survey data. Crucially, however, the model assumes that an individual bird takes no avoiding action when encountering a turbine, so an adjustment must also be made for avoidance behaviour.

In this paper, we examine critically the estimation and use of avoidance rates in conjunction with the collision risk model (CRM). The sensitivity of predicted mortality to errors in estimated avoidance rates is assessed in three studies that have used the CRM. It should be noted that we consider only direct mortality caused by wind turbine collisions, but we accept that there may be other indirect effects on bird populations such as disturbance, displacement and loss of habitat (Langston & Pullan 2003, Percival 2005, Fox *et al*. 2006) that are outside the scope of this paper.

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Carretea, M., J.A. Sánchez-Zapatab, J.R. Benítezc, M. Lobónc and J.A. Donázara. 2009. Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptors. Biological Conservation 14:2954-2961.

Abstract: Wind-farms receive public and governmental support as an alternative energy source mitigating air pollution. However, they can have adverse effects on wildlife, particularly through collision with turbines. Research on wind-farm effects has focused on estimating mortality rates, behavioural changes or interspecific differences in vulnerability. Studies dealing with their effects on endangered or rare species populations are notably scarce. We tested the hypothesis that wind-farms increase extinction probability of long-lived species through increments in mortality rates. For this purpose, we evaluate potential consequences of wind-farms on the population dynamics of a globally endangered long-lived raptor in an area where the species maintains its greatest stronghold and wind-farms are rapidly increasing. Nearly one-third of all breeding territories of our model species are in wind-farm risk zones. Our intensive survey shows that wind-farms decrease survival rates of this species differently depending on individual breeding status. Consistent with population monitoring, population projections showed that all subpopulations and the meta-population are decreasing. However, population sizes and, therefore, time to extinction significantly decreased when wind-farm mortality was included in models. Our results represent a qualitative warning exercise showing how very low reductions in survival of territorial and non-territorial birds associated with

wind-farms can strongly impact population viability of long-lived species. This highlights the need for examining long-term impacts of wind-farms rather than focusing on short-term mortality, as is often promoted by power companies and some wildlife agencies. Unlike other non-natural causes of mortality difficult to eradicate or control, wind-farm fatalities can be lowered by powering down or removing risky turbines and/or farms, and by placing them outside areas critical for endangered birds.

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Drewitt, A.L. and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148**:**29–42

Abstract: The potential effects of the proposed increase in wind energy developments on birds are explored using information from studies of existing wind farms. Evidence of the four main effects, collision, displacement due to disturbance, barrier effects and habitat loss, is presented and discussed. The consequences of such effects may be direct mortality or more subtle changes to condition and breeding success. The requirements for assessing the impact of future developments are summarized, including relevant environmental legislation and appropriate methods for undertaking baseline surveys and post-construction monitoring, with particular emphasis on the rapidly developing area of offshore wind farm assessments. Mitigation measures which have the potential to minimize impacts are also summarized. Finally, recent developments in the monitoring and research of wind energy impacts on birds are outlined and some areas for future work are described.

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Drewitt, A.L. and R.H.W. Langston. 2008. Collision Effects of Wind-power Generators and Other Obstacles on Birds**.** Annals of the New York Academy of Science 1134: 233–266.

Abstract: There is extensive literature on avian mortality due to collision with man-made structures, including wind turbines, communication masts, tall buildings and windows, power lines, and fences. Many studies describe the consequences of bird-strike rather than address the causes, and there is little data based on long-term, standardized, and systematic assessments. Despite these limitations, it is apparent that bird-strike is a significant cause of mortality. It is therefore important to understand the effects of this mortality on bird populations. The factors which determine avian collision risk are described, including location, structural attributes, such as height and the use of lighting, weather conditions, and bird morphology and behavior. The results of incidental and more systematic observations of bird-strike due to a range of structures are presented and the implications of collision mortality for bird populations, particularly those of scarce and threatened species susceptible to collisions, are discussed. Existing measures for reducing collision mortality are described, both generally and specifically for each type of structure. It is concluded that, in some circumstances, collision mortality can adversely affect bird populations, and that greater effort is needed to derive accurate estimates of mortality levels locally, regionally, and nationally to better assess impacts on avian populations. Priority areas for future work are suggested, including further development of remote technology to monitor collisions, research into the causes of bird-strike, and the design of new, effective mitigation measures.

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Fielding, A.H., D.P. Whitfield, and D.R.A. McLeod. 2006. Spatial association as an indicator of the potential for future interactions between wind energy developments and golden eagles *Aquila chrysaetos* in Scotland. Biological Conservation 13:359-369

Abstract: Despite their environmental benefits in generating electricity without emission of 'greenhouse' gases, wind farms have attracted controversy with regard to their impacts on birds, especially golden eagles *Aquila chrysaetos*. Evidence from USA studies suggest eagle fatalities through collision with turbines may be the main potential impact whereas for breeding eagles in Scotland, displacement from wind farm areas (indirect habitat loss) may be the primary impact. In this study, we examined the co-occurrence potential for golden eagles and wind farms in Scotland by documenting the spatial association between wind farm proposals and breeding eagle territories and areas potentially suitable for non-breeding eagles. Although there were records for over 500 wind farm proposals at various stages of development, relatively few coincided with eagle territories (ca. 4% of territories had a proposal within 3 km of territory centre). Similarly, only 2% of habitat predicted to be suitable for non-breeding eagles overlapped with proposed or installed wind farm areas. Moreover, estimates of the potential for electricity generation from all wind farm proposals, with respect to government targets for renewable energy supplies, suggested most proposals were unlikely to be constructed. We conclude that in comparison with other constraints on Scotland's golden eagles, notably persecution, wind farms should not represent a serious concern if best practice in planning their location and minimising their impact are maintained. Potential future regional pressures on breeding eagles from wind farms are highlighted, however, and uncertainty of impact with respect to displacement or collision fatalities requires continued scrutiny.

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Hoover, S.L. and M.L. Morrison. 2005. Behavior of Red-Tailed Hawks in a Wind Turbine Development. Journal of Wildlife Management 69:150-159.

Abstract: Birds flying within windfarms can be killed when they collide with wind turbines. Raptors, especially red-tailed hawks (*Buteo jamaicensis*), are more susceptible to collisions than other birds, which may be attributable to their specific foraging and flight behavior. To more fully understand the problem, and to reduce raptor mortality, it is necessary to acquire more information on habitat use and flight behavior by raptors inhabiting windfarms. Between June 1999 and June 2000, we watched raptors for 346 hours in the Altamont Pass Wind Resource Area, the largest windfarm in North America. We recorded flight behavior in relation to characteristics of the topography such as slope aspect, elevation, and inclination and in relation to various weather variables including wind speed and wind direction. We found that red-tailed hawk behavior and their use of slope aspect differed according to wind speed. Hawks perched more often in weak winds than in strong. Red-tailed hawks were more likely to soar during low wind conditions and kite during strong wind, particularly on hillsides that faced into the wind as opposed to hillsides shielded from the wind. This is likely a result of their use of deflection updrafts for lift during flight. During our study, when winds were strong and from the south–southwest, kiting behavior occurred on south–southwestern facing slopes with inclines of greater than 20% and peak elevations greater than adjacent slopes. Accordingly, mitigation measures to decrease red-tailed hawk fatalities should be directed specifically to these areas and others fitting this general model. Wind farm managers can power down turbines at the top of these hazardous slopes when they pose the greatest danger—when winds are strong and facing perpendicularly to the slope.

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Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd, and S.A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30:879-887.

Abstract: In 1994 Xcel Energy initiated a wind-power development project in southwestern Minnesota that will eventually produce 425 megawatts (MW) of electricity. During our study the wind farm consisted of 3 phases of development totaling 354 turbines capable of generating 236 MW, depending on wind speed. We assessed effects of the wind farm on birds from 1996 to 1999, with 55 documented collision fatalities. Recovered carcasses included 42 passerines, 5 waterbirds, 3 ducks, 3 upland game birds, 1 raptor, and 1shorebird. Most fatalities (71 %) were likely migrants through the area, 20% were species that likely were breeding in the study area, and 9% were permanent residents. Wind farm-related mortality was estimated by extrapolating the number of carcasses found at a sample of the turbines and adjusting for scavenger removal and searcher efficiency rates. We estimated total annual mortality at 72 (90% CI=36-108) in the Phase 1 wind farm, 324 (90%/ CI=175-473) in the Phase 2 wind farm, and 613 (90% CI=132-1093) in the Phase 3 wind farm. The Phase 3 wind-farm estimate was based on 1 year of data and was largely influenced by a single mortality event involving 14 passerines at 2 adjacent turbines during 1 night. Radar data indicated that approximately 3.5 million birds migrate over the wind farm each year; however, the proportion of birds flying at heights susceptible to turbine collisions is not known. Wind-power development will likely contribute to cumulative collision mortality of birds in the United States.

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Kikuchi, R. 2008. Adverse impacts of wind power generation on collision behaviour of birds and anti-predator behaviour of squirrels. Journal for Nature Conservation 16: 44-55

Summary: Wind power is a fast-growing energy source for electricity production, and some environmental impacts (e.g. noise and bird collision) are pointed out. Despite extensive land use (2600–6000 m^2/MW), it is said that most of these impacts have been resolved by technological development and proper site selection. The results in this paper suggest that: (i) wind farms kill millions of birds yearly around the world, and the high mortality of rare

raptors is of particular concern; (ii) wind farms on migration routes are particularly dangerous, and it is difficult to find a wind power site away from migration routes because there is no guarantee that migration routes will not vary; (iii) according to the presented model of collision probability, the rotor speed does not make a significant difference in collision probability; the hub is the most dangerous part, and large birds (e.g. raptors) are at great risk; and, (iv) based on the field observation of squirrels' vocalisation (i.e. anti-predator behaviour), there are behavioural differences between squirrels at the wind turbine site and those at the control site. Noise from wind turbines (when active) may interfere with the lives of animals beneath the wind turbines. US Government guidelines and the Bern Convention's report have described adverse impacts of wind energy facilities on wildlife and have put forward recommendations. In addition to these documents, the following points derived from the discussion in this paper should be noted for the purpose of harmonising wind power generation with wildlife conservation: (i) engineers need to develop a turbine form to reduce the collision risk at the hub; (ii) institute long-term monitoring, including a comparison between bird mortality before and after construction; and (iii) further evaluate impacts of turbine noise on anti-predator wildlife vocalisations.

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Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document. Journal of Wildlife Management 71:2449-2486.

Abstract: Our purpose is to provide researchers, consultants, decision-makers, and other stakeholders with guidance to methods and metrics for investigating nocturnally active birds and bats in relation to utility-scale wind-energy development. The primary objectives of such studies are to 1) assess potential impacts on resident and migratory species, 2) quantify fatality rates on resident and migratory populations, 3) determine the causes of bird and bat fatalities, and 4) develop, assess, and implement methods for reducing risks to bird and bat populations and their habitats. We describe methods and tools and their uses, discuss limitations, assumptions, and data interpretation, present case studies and examples, and offer suggestions for improving studies on nocturnally active birds and bats in relation to wind-energy development. We suggest best practices for research and monitoring studies using selected methods and metrics, but this is not intended as cookbook. We caution that each proposed and executed study will be different, and that decisions about which methods and metrics to use will depend upon several considerations, including study objectives, expected and realized risks to bird and bat populations, as well as budgetary and logistical considerations. Developed to complement and extend the existing National Wind Coordinating Committee document "Methods and Metrics for Assessing Impacts of Wind Energy Facilities on Wildlife" (Anderson et al. 1999), we provide information that stakeholders can use to aid in evaluating potential and actual impacts of wind power development on nocturnally active birds and bats. We hope that decision-makers will find these guidelines helpful as they assemble information needed to support the permitting process, and that the public will use this guidance document as they participate in the permitting processes. We further hope that the wind industry will find valuable guidance from this document when 1) complying with data requirements as a part of the permitting process, 2) evaluating sites for potential development, 3) assessing impacts of operational wind-energy facilities, and 4) mitigating local and cumulative impacts on nocturnally active birds and bats.

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Larkin, R.P. and B.A. Frase. 1998. Circular paths of birds flying near a broadcasting tower in cloud. Journal of Comparative Psychology 102(1): 90-93.

Abstract: Tracks of birds migrating at night near an illuminated 308-m-tall broadcasting tower were recorded by using radar. During a period when low clouds surrounded the tower, birds flew in arcs or circles centered on the tower and having radii in excess of 100 m. Under clear skies or beneath cloud layers, arcs and circles were not observed. The data may contribute to understanding the behavioral mechanism of massive bird kills at tall lighted structures.

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Leddy, K.L., K.F. Higgins, and D.E. Naugle. 1999. Effects of Wind Turbines on Upland Nesting Birds in Conservation Reserve Program Grasslands. Wilson Bulletin 111:100-104

Abstract: Grassland passerines were surveyed during summer 1995 on the Buffalo Ridge Wind Resource Area in southwestern Minnesota to determine the relative influence of wind turbines on overall densities of upland nesting birds in conservation Reserve Program (CRP) grasslands. Birds were surveyed along 40 m fixed width transects that were placed along wind turbine strings within three CRO fields and in three CRP fields without turbines. Conservation Reserve Program grasslands without turbines and areas located 180 m from turbines supported higher densities (261.0-312.5 males/100 ha) of grassland birds than areas within 80 m of turbines (58.2-128.0 males/100 ha). Human disturbance, turbine noise, and physical movements of turbines during operation may have disturbed nesting birds. We recommend that wind turbines be placed within cropland habitats that support lower densities of grassland passerines than those found in CRP grasslands.

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Mabee, T.J., B.A. Cooper, J.H. Plissner, and D.P. Young. 2006. Nocturnal Bird Migration Over an Appalachian Ridge at a Proposed Wind Power Project. Wildlife Society Bulletin 34:682-690.

Abstract: Characteristics of nocturnal bird migration are poorly understood for many regions of the United States. This information will be critical in areas where wind power projects are proposed. We used portable marine radar to conduct a nocturnal bird migration study at multiple sites along the Allegheny Front, West Virginia, on 45 nights during autumn 2003, to document migration characteristics at a proposed wind power project. Nocturnal passage rates were highly variable among nights, ranging from 8 to 852 targets/km/hour, with a seasonal mean of 241 ± 33 targets/km/hour at the primary (central) study site and 199 targets/km/hour for the entire proposed development. Mean flight altitudes also were highly variable among nights, ranging from 214 to 769 m above ground level (agl), with a mean flight altitude of 410 ± 2 m agl. Flight directions indicated that most migrants crossed, rather than followed, the Allegheny Front ridgeline. We believe portable marine radars, when coupled with a rigorous study design, can collect important baseline information on avian migration and address site specific questions posed at proposed developments. Concurrent collection of low-altitude migration and avian fatality data could help elucidate which metrics are most useful for predicting avian fatalities at wind power developments.

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Osborn, R.G., K.F. Higgins, R.E. Usgaard, C.D. Dieter, and R.D. Neiger. 2000. Bird Mortality Associated with Wind Turbines at the Buffalo Ridge Wind Resource Area, Minnesota. American Midland Naturalist 143:41-52

Abstract -Recent technological advances have made wind power a viable source of alternative energy production and the number of windplant facilities has increased in the United States. Construction was completed on a 73 turbine, 25 megawatt windplant on Buffalo Ridge near Lake Benton, Minnesota in Spring 1994. The number of birds killed at existing windplants in California caused concern about the potential impacts of the Buffalo Ridge facility on the avian community. From April 1994 through Dec. 1995 we searched the Buffalo Ridge windplant site for dead birds. Additionally, we evaluated search efficiency, predator scavenging rates and rate of carcass decomposition. During 20 mo of monitoring we found 12 dead birds. Collisions with wind turbines were suspected for 8 of the 12 birds. During observer efficiency trials searchers found 78.8% of carcasses. Scavengers removed 39.5% of carcasses during scavenging trials. All carcasses remained recognizable during 7 d decomposition trials. After correction for biases we estimated that approximately 36 + 12 birds (<1 dead bird per turbine) were killed at the Buffalo Ridge windplant in 1 y. Although windplants do not appear to be more detrimental to birds than other man-made structures, proper facility siting is an important first consideration in order to avoid unnecessary fatalities.

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Osborn, R.G., C.D. Dieter, K.F. Higgins, and R.E. Usgaard. 1997. Bird Flight Characteristics Near Wind Turbines in Minnesota. American Midland Naturalist 139:29-38.

Abstract: During 1994-1995, we saw 70 species of birds on Buffalo Ridge Wind Resource Area. In both years bird abundance peaked in spring. Red-winged blackbirds (*Agelaius phoeniceus*), Mallards (*Anas platyrhynchos*), common grackles (*Quiscalus quiscula*), and barn swallows (*Hirundo rustica*) were the species most commonly seen. Most birds (82-84%) flew above or below the height range of wind turbine blades (22-55 m). The Buffalo Ridge Wind Resource Area poses little threat to resident or migrating birds at its current operating level.

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Pearce-Higgins, J.W., L. Stephen, R.H.W. Langston, and J.A. Bright. 2008. Assessing the cumulative impacts of wind farms on peatland birds: a case study of golden plover *Pluvialis apricaria* in Scotland. Mires and Peat 4:1-3.

Summary: The distribution of golden plover across Scotland was modelled using land cover and management variables, and used to highlight the spatial association between golden plover abundance and current and proposed wind farm developments. Overlap was greatest in three biogeographical zones (the Western Isles, the Western Central Belt and the Borders Hills) and was estimated at ca. 5% of the biogeographical population in each case. New field data were used to predict the effects of wind farm development on golden plover populations, employing a conservative analytical approach to detect statistically significant wind farm related effects. The results provide evidence of significant avoidance of wind turbines by breeding golden plovers to a distance of at least 200 metres. Furthermore, wind farm sites appear to support lower densities of golden plover than predicted by the distribution model for sites without wind farms. Therefore, there is evidence for negative effects of wind farm developments on golden plover, and we suggest strategies to reduce any potential conflict between the need to promote wind energy and the need to maintain golden plover populations.

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Pearce-Higgins, J.W., L. Stephen, R.H.W. Langston, I.P. Bainbridge and R. Bullman. 2009. The distribution of breeding birds around upland wind farms. Journal of Applied Ecology 46:1323-1331.

Summary:
1. There is an urgent need for climate change mitigation, of which the promotion of renewable energy, such as from wind farms, is an important component. Birds are expected to be sensitive to wind farms, although effects vary between sites and species. Using data from12 upland wind farms in the UK, we examine whether there is reduced occurrence of breeding birds close to wind farm infrastructure (turbines, access tracks and overhead transmission lines).To our knowledge, this is the first such multi-site comparison examining wind farm effects on the distribution of breeding birds.
2. Bird distribution was assessed using regular surveys during the breeding season. We took a conservative analytical approach, with bird occurrence modelled as a function of habitat, before examining the additional effects of wind farm proximity.
3. Seven of the 12 species studied exhibited significantly lower frequencies of occurrence close to the turbines, after accounting for habitat variation, with equivocal evidence of turbine avoidance in a further two. No species were more likely to occur close to the turbines. There was no evidence that raptors altered flight height close to turbines. Turbines were avoided more strongly than tracks, whilst there was no evidence for consistent avoidance of overhead transmission lines connecting sites to the national grid.
4. Levels of turbine avoidance suggest breeding bird densities may be reduced within a 500-m buffer of the turbines by 15–53%, with buzzard *Buteo buteo*, hen harrier *Circus cyaneus*, golden plover *Pluvialis apricaria*, snipe *Gallinago gallinago*, curlew *Numenius arquata* and wheatear *Oenanthe oenanthe* most affected.
5. Despite being a correlative study, with potential for Type I error, we failed to detect any systematic bias in our likelihood of detecting significant effects.
6. Synthesis and applications. This provides the first evidence for consistent and significant effects of wind farms on a range of upland bird species, emphasizing the need for a strategic approach to ensure such development avoids areas with high densities of potentially vulnerable species. Our results reduce the uncertainty over the magnitude of such effects, and will improve future environmental impacts assessments.

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Smallwood, K.S., C.G. Thelander, M.L. Morrison, and L.M. Rugge. 2007. Burrowing Owl Mortality in the Altamont Pass Wind Resource Area. Journal of Wildlife Management 71:1513-1524.

Abstract: We estimated wind turbines in the Altamont Pass Wind Resource Area (APWRA), California, USA, kill >100 burrowing owls (*Athene cunicularia hypugaea*) annually, or about the same number likely nesting in the APWRA. Turbine-caused mortality was up to 12 times greater in areas of rodent control, where flights close to the rotor plane were disproportionately more common and fatalities twice as frequent as expected. Mortality was highest during January through March. Burrowing owls flew within 50 m of turbines about 10 times longer than expected, and they flew close to wind turbines disproportionately longer within the sparsest turbine fields, by turbines on tubular towers, at the edges of gaps in the turbine row, in canyons, and at lower elevations. They perched, flew close to operating turbine blades, and collided disproportionately more often at turbines with the most cattle dung within 20 m, with the highest densities of ground squirrel (*Spermophilus beecheyi*) burrow systems within 15 m, and with burrowing owl burrows located within 90 m of turbines. A model of relative collision threat predicted 29% of the 4,074 turbines in our sample to be more dangerous, and these killed 71% of the burrowing owls in our sample. This model can help select the most dangerous turbines for shutdown or relocation. All turbines in the APWRA could be shut down and blades locked during winter, when 35% of the burrowing owls were killed but only 14% of the annual electricity was generated. Terminating rodent control and installing flight diverters at the ends of turbine rows might also reduce burrowing owl mortality, as might replacing turbines with new-generation turbines mounted on taller towers.

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Smallwood, K.S. 2007. Estimating Wind Turbine–Caused Bird Mortality. Journal of Wildlife Management 71(8): 2781-2791.

Mortality estimates are needed of birds and bats killed by wind turbines because wind power generation is rapidly expanding worldwide. A mortality estimate is based on the number of fatalities assumed caused by wind turbines and found during periodic searches, plus the estimated number not found. The 2 most commonly used estimators adjust mortality estimates by rates of searcher detection and scavenger removal of carcasses. However, searcher detection trials can be biased by the species used in the trial, the number volitionally placed for a given fatality search, and the disposition of the carcass on the ground. Scavenger removal trials can be biased by the metric representing removal rate, the number of carcasses placed at once, the duration of the trial, species used, whether carcasses were frozen, whether carcasses included injuries consistent with wind turbine collisions, season, distance from the wind turbines, and general location. I summarized searcher detection rates among reported trials, and I developed models to predict the proportion of carcasses remaining since the last fatality search. The summaries I present can be used to adjust previous and future estimates of mortality to improve comparability. I also identify research directions to better understand these and other adjustments needed to compare mortality estimates among wind farms.

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Smallwood, K.S. and C. Thelander. 2008. Bird Mortality in the Altamont Pass Wind Resource Area, California. Journal of Wildlife Management 72:215-223.

Abstract: The 165-km^2 Altamont Pass Wind Resource Area (APWRA) in west-central California includes 5,400 wind turbines, each rated to generate between 40 kW and 400 kW of electric power, or 580 MW total. Many birds residing or passing through the area are killed by collisions with these wind turbines. We searched for bird carcasses within 50 m of 4,074 wind turbines for periods ranging from 6 months to 4.5 years. Using mortality estimates adjusted for searcher detection and scavenger removal rates, we estimated the annual wind turbine–caused bird fatalities to number 67 (80% CI = 25–109) golden eagles (*Aquila chrysaetos*), 188 (80% CI = 116–259) red-tailed hawks (*Buteo jamaicensis*), 348 (80% CI = −49 to 749) American kestrels (*Falco sparverius*), 440 (80% CI = −133 to 1,013) burrowing owls (*Athene cunicularia hypugaea*), 1,127 (80% CI = −23 to 2,277) raptors, and 2,710 (80% CI = −6,100 to 11,520) birds. Adjusted mortality estimates were most sensitive to scavenger removal rate, which relates to the amount of time between fatality searches. New on-site studies of scavenger removal rates might warrant revising mortality estimates for some small-bodied bird species, although we cannot predict how the mortality estimates would change. Given the magnitude of our mortality estimates, regulatory agencies and the public should decide whether to enforce laws intended to protect species killed by APWRA wind turbines, and given the imprecision of our estimates, directed research is needed of sources of error and bias for use in studies of bird collisions wherever wind farms are developed. Precision of mortality estimates could be improved by deploying technology to remotely detect collisions and by making wind turbine power output data available to researchers so that the number of fatalities can be related directly to the actual power output of the wind turbine since the last fatality search.

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Smallwood, K.S., L. Rugge, M.L. Morrison. 2009. Influence of Behavior on Bird Mortality in Wind Energy Developments. Journal of Wildlife Management 73(7):1082-109

Abstract: As wind power generation is rapidly expanding worldwide, there is a need to understand whether and how preconstruction surveys can be used to predict impacts and to place turbines to minimize impacts to birds. Wind turbines in the 165-km^2 Altamont Pass Wind Resource Area (APWRA), California, USA, cause thousands of bird fatalities annually, including hundreds of raptors. To test whether avian fatality rates related to rates of utilization and specific behaviors within the APWRA, from March 1998 to April 2000 we performed 1,959 30-minute behavior observation sessions (360° visual scans using binoculars) among 28 nonoverlapping plots varying from 23 ha to 165 ha in area and including 10–67 turbines per plot, totaling 1,165 turbines. Activity levels were highly seasonal and species specific. Only 1% of perch time was on towers of operating turbines, but 22% was on towers of turbines broken, missing, or not operating. Of those species that most often flew through the rotor zone, fatality rates were high for some (e.g., 0.357 deaths/megawatt of rated capacity [MW]/yr for red-tailed hawk [*Buteo jamaicensis*] and 0.522 deaths/MW/yr for American kestrel [*Falco sparverius*]) and low for others (e.g., 0.060 deaths/MW/yr for common raven [*Corvus corax*] and 0.012 deaths/MW/yr for turkey vulture [*Cathartes aura*]), indicating specific behaviors or visual acuity differentiated these species by susceptibility to collision. Fatality rates did not correlate with utilization rates measured among wind turbine rows or plots for any species except burrowing owl (*Athene cunicularia*) and mallard (*Anas platyrhynchos*). However, mean monthly fatality rates of red-tailed hawks increased with mean monthly utilization rates ($r^2 = 0.67$) and especially with mean monthly flights through turbine rows ($r^2 = 0.92$). Fatality rates increased linearly with rates of utilization ($r^2 = 0.99$) and flights near rotor zones ($r^2 = 1.00$) for large raptor species and with rates of perching ($r^2 = 0.13$) and close flights ($r^2 = 0.77$) for small non-raptor species. Fatalities could be minimized or reduced by shutting down turbines during ≥1 season or in very strong winds or by leaving sufficiently large areas within a wind farm free of wind turbines to enable safer foraging and travel by birds.

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Stewart, G.B., A.S. Pullin, and C.F. Coles. 2007. Poor evidence-base for assessment of windfarm impacts on birds. Environmental Conservation 34(1):1-11.

Abstract: Concerns about anthropogenic climate change have resulted in promotion of renewable energy sources, especially wind energy. A concern raised against widespread windfarm development is that it may negatively impact bird populations as a result of bird collision with turbines, habitat loss and disturbance. Using systematic review methodology bird abundance data were synthesized from 19 globally-distributed windfarms using meta-analysis. The effects of bird taxon, turbine number, power, location, latitude, habitat type, size of area, time since operation, migratory status of the species and quality of evidence were analysed using meta-regression. Although the synthesized data suggest a significant negative impact of windfarms on bird abundance, there is considerable variation in the impact of individual windfarm sites on individual bird species, and it is unclear if the negative impact is a decline in population abundance or a decline in use owing to avoidance. Anseriformes experienced greater declines in abundance than other taxa, followed by Charadriiformes, Falconiformes and Accipitriformes, and Passeriformes. Time since windfarms commenced operation also had a significant impact on bird abundance, with longer operating times resulting in greater declines in abundance than short operating times. Other variables, including turbine number and turbine power either had very weak but statistically significant effects or did not have a significant effect on bird abundance. Windfarms may have significant biological impacts, especially over longer time scales, but the evidence-base is poor, with many studies being methodologically weak, and more long-term impact assessments are required. There is clear evidence that Anseriformes (wildfowl) and Charadriiformes (waders) experience declines in abundance, suggesting that a precautionary approach should be adopted to windfarm development near aggregations of these taxa in offshore and coastal locations. The impact of windfarm developments on bird populations must also be viewed in the context of the possible impact of climate change in the absence of windfarms.

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Tellería, J.L. 2009. Wind power plants and the conservation of birds and bats in Spain: a geographical assessment. Biodiversity and Conservation 18:1781-1791.

Abstract: The number of wind power plants installed in Spain has increased dramatically, and many are located in important wildlife areas. This paper explores the geographical overlap of wind power plants with the ranges of flying vertebrate species. The list of animals studied includes bats, soaring birds, and other birds that may be killed by turbines. Results show that the 10 × 10 km UTM squares occupied by wind power plants fell within the range of more bat and bird species than squares free of these infrastructures. For species included in the Spanish Red List,

there were more wind power plants than expected inside the range of two raptors (*Neophron percnopterus* and *Circus pygargus*) and less than expected in six species (*Ciconia nigra*, *Aquila adalberti, Hieraetus fasciatus Myotis capaccinii*, *Rhinolophus mehelyi* and *Myotis myotis*). The rest of endangered species (15) had a range occupation similar to that predicted by random sampling, a result that reflects a poor strategy to prevent the overlap. These patterns may be explained by the small amount of overlap of the range of many of these animals with the windiest areas in Spain, where wind power plants are concentrated today. However, this situation is changing rapidly with the densification and expansion of wind power plants promoted under the Spanish Plan of Renewable Energies. This may produce the occupation of many areas important to bird and bat conservation, and therefore preventive measures should be implemented to protect these species and their habitats.

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Tellería, J.L. 2009. Overlap between wind power plants and Griffon Vultures *Gyps fulvus* in Spain. Bird Study 56(2): 268-271.

Capsule: The huge expansion of wind power plants has already occupied a significant part of the breeding range of the Spanish population of Griffon Vultures.

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Tellería, J.L. 2009. Potential impacts of wind farms on migratory birds crossing Spain. Bird Conservation International 19:131-136.

Summary: Over recent years, Spain has undergone a huge expansion in the number of wind farms, many of which extend across regions crossed by migratory birds that winter in the Iberian Peninsula and Africa. This paper explores the potential impact these structures have on the massive flow of birds along the western Pyrenean flyway. Ringing recoveries of migratory Wood Pigeons Columba palumbus were used in the study to depict the movements of migratory birds and these were then compared to the distribution of wind farms. The main flow of pigeons (50% of ringing recoveries) was concentrated in a belt 50 km wide. Although the wind farms were mainly distributed outside this central belt, they intercepted an adjacent sector where a considerable number of ringed pigeons (30%) were recorded. This means that the two central bands (100 km wide) accounted for around 80% of the total number of Wood Pigeons crossing the region. These results suggest the need for a scrupulous evaluation of the potential impact of wind farms on migratory birds along this flyway, particularly the cumulative effect on populations crossing the region regularly. In view of the rapid expansion of wind farms in northern Spain, enforcement of the application of EU regulations on preventive measures to protect migratory species is urgently needed.

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Walker, D., M. McGrady, A. McCluskie, M. Madders and D.R.A. McLeod. 2005. Resident Golden Eagle ranging behaviour before and after construction of a windfarm in Argyll. Scottish Birds 25: 24–40

Abstract: Resident Golden Eagle ranging behaviour was monitored over 776 observation hours before and after construction of a windfarm in Argyll, western Scotland between 1997 and 2004. Overall size of the eagle range that was potentially affected by the windfarm (for male, female and both eagles) was similar before and after construction. Eagles appeared to change their ranging to avoid the windfarm site. Once built the windfarm was over flown mostly when other eagles intruded on the territory. An area of plantation forestry was felled with the aim of mitigating the potential loss of foraging habitat to the windfarm, and drawing eagles away from the windfarm thereby reducing collision risk. Eagles were seen in the tree cleared area 3 times more often after felling than before felling, and the shift in ranging was away from the windfarm and in the direction of the felled area. These findings are from a single pair and should be used cautiously when applied to other, similar, situations. However, they are an important first step in understanding the likely effects of windfarms on eagles.

Article Type: Technical Report

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American Wind Energy Association. 2008. Wind Energy Siting Handbook. 183 pp.

(Pg. 5-11) Avoidance of specific habitat features known to be attractive to threatened, endangered, or species of concern is the best way to minimize habitat impacts. Developers can mitigate potential impacts by obtaining baseline data that show the pattern of bird use. Ideal sites are those that do not include high activity within the elevation zones of the rotor swept area or in locations where turbines would be sited. These data can include point counts that include mapping of flight paths, and day- and night-time radar studies. Financial contribution o research the interactions of birds and wind projects and their prevention, minimization and mitigation is another possible mitigation measure.

American Wind Energy Association. 2009. Resources: U.S. Wind Energy Projects, as of June 27, 2009. http://www.awea.org/projects/. Accessed July 23, 2009.

Contains maps of current and potential wind energy projects.

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Association of Fish and Wildlife Agencies (AFWA) and U.S. Fish and Wildlife Service. 2007. Wind power siting, incentives, and wildlife guidelines in the United States. Research conducted by: Jodi Stemler Consulting, Denver, CO. 134 pp.

In review of state fish and wildlife agency response to wind power siting, it is apparent that this is a relatively new issue for most agencies and that the majority can provide suggestions to developers but most existing guidelines are voluntary. Some states' guidelines were developed primarily by fish and wildlife agency and focused entirely on wildlife issues, while others included wildlife recommendations among guidelines ranging from public safety and recreational considerations to sound and visual impacts. (page 4) Siting rules listed for each state.

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Band, W., M. Madders, and D.P. Whitfield. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. pp. 259-275. *In:* de Lucas, M., G.F.E. Janss, et al. (Ed.) Birds and wind farms: risk assessment and mitigation. Quercus, Madrid, Spain.

No abstract available on line.

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Barrios, L. and A. Rodríguez. 2007. Spatiotemporal patterns of bird mortality at two wind farms of southern Spain. pp. 229-239. *In:* de Lucas, M., G.F.E. Janss, et al. (Ed.) Birds and wind farms: risk assessment and mitigation. Quercus, Madrid, Spain.

No abstract available on line.

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Chamberlain, D., S. Freeman, M. Rehfisch, T. Fox, and M. Desholm. 2005. Appraisal of Scottish Natural Heritage's Wind Farm Collision Risk Model and its Application. British Trust for Ornithology Research Report 401. http://www.iberica2000.org/documents/eolica/REPORTS/COLLISION_MODEL_BTO.pdf

Executive Summary:
1. There are concerns over the potential impacts of wind farms on bird mortality rates due to turbine collisions. Scottish Natural Heritage (SNH) has produced a model to predict collision risk within the sweep area of the turbine rotors, assuming no avoiding action, based on input parameters derived from bird survey data (number of birds per unit time flying through the sweep area) and structural and operational variables describing the wind turbines. Mortality rates are determined by combining predicted collision risk with the numbers of birds at risk and bird avoidance rates when turbines are encountered.
2. This report critically evaluates the SNH collision risk model and its use with avoidance rates to predict bird mortality. Specifically the aims were: (i) To assess the underlying mathematics and assumptions of the model; (ii)

To identify those input parameters which vary or are estimated, and which can have a large effect on the model outputs; (iii) To identify any flaws or limitations in the calculation of avoidance rates; (iv) To provide an aid to interpretation of model outputs for non-specialists including a checklist of input parameters for particular scrutiny and any caveats attached to these; (v) To provide recommendations for improvements to the model, its application and interpretation, including data requirements and survey methodologies to adequately parameterize the model, and to provide caveats for the use and interpretation of the model.

3. The model was found to be generally statistically sound. There were two features that could be improved upon. First, it would be more accurate to use a more precise method of integration such as Simpson's rule or the trapezoidal method rather than the simpler rectangular method employed. However, use of these more accurate methods made very little difference to model predictions in the examples here. Second, greater consideration needs to be given of the effects of overlapping rotors on collision risk, although a formal analysis would require a considerable degree of model development.

4. Input parameters to the collision risk model were varied in turn (within a realistic range) in order to assess the sensitivity of predicted collision risk to possible measurement errors. Variations in bird length and wing span had only small effects on collision risk. Bird speed was non-linearly related to collision risk and its variation had a greater effect on predicted collision risk than bird size. Predicted mortality increased exponentially at very low speeds (< 5m/s), but it is doubtful whether many birds fly at this speed.

5. There were non-linear effects of rotor diameter, rotation period and rotor blade pitch angle. Predicted collision risk increased exponentially with decreases in the former two variables. As these are known variables (rather than estimated) it should be possible for very accurate measurements to be used in the model.

6. The outputs from the collision risk models were combined with bird data to predict the mortality rate (assuming no avoiding action). Estimates are made of the number of birds at risk in a given time period (usually from observational survey data of birds flying at risk height through the proposed wind farm). Errors in bird counts and especially of the numbers at risk height will translate into directly proportional errors in predicted mortality rate.

7. The final calculation of mortality incorporates avoidance rates simply by multiplying (1 –avoidance rate) by collision risk and bird numbers at risk. Avoidance rates used in the examples presented were high (>0.90) and therefore resulted in a large adjustment to predicted mortality. Equally, small errors in avoidance rate were shown to result in large percentage changes in predicted mortality rates.

8. Further case studies were used to illustrate the effects of varying different parameters on predicted mortality. In each case, change in avoidance rate had the greatest effect on predicted mortality. In one example, a 10% change in all input parameters to the collision risk model and in numbers of birds at risk resulted in a 52% increase in predicted mortality. A 10% decrease in avoidance rate alone resulted in an increase of over 2000% in predicted mortality.

9. Avoidance rates are poorly known. Estimates are usually derived from the ratio of mortality (estimated by corpse searches) to birds in the risk area, both of which are subject to (sometimes considerable) error. This error will therefore have a large effect on predicted mortality. Given the clear species and site-specific variations in mortality rates, it is deemed unacceptable to use avoidance rates derived from other studies without clear and rigorous justification.

10. It is imperative that further research is carried out on avoidance rates. It is suggested that remote survey methods using surveillance azimuth radar and thermal infrared imagery, for example, be used to assess the behaviour of birds encountering wind farms and any avoiding action taken. Ideally, this would be possible over a range of species and environmental conditions (seasonal, diurnal and weather variations).

11. Mortality is likely to be increased in poor visibility (e.g. at dusk or in poor weather), yet many surveys take place only when (human) visibility is good. Surveys are improved by use of remote technologies as outlined above, so movements under a range of conditions are known. Use of these techniques is not routine, but it is suggested that they should be part of any EIA.

12. Similarly, the relative sensitivity of collision risk to bird speed necessitates further research using remote technologies. In each case considered, bird speed was derived from a single source and was based on radar data for birds migrating. It is conceivable that there may be considerable variation in bird speed depending on species and prevailing conditions.

13. The collision risk model is a robust tool to predict collision risk in the absence of avoidance rates. However, the latter factor has a very large effect on predicted mortality. It is also very poorly studied. For these reasons, we are unable to recommend use of the collision risk model without further research into avoidance rates. The latter must be considered a very high priority.

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Dooling, R. 2002. Avian Hearing and the Avoidance of Wind Turbines. Report prepared for the National Renewable Energy Laboratory. **http://www.nrel.gov/wind/pdfs/30844.pdf**

Executive Summary and Recommendations: This report provides a complete summary of what is known about basic hearing capabilities in birds in relation to the characteristics of noise generated by wind turbines. It is a review of existing data on bird hearing with some preliminary estimates of environmental noise and wind turbine noise at Altamont Pass, California, in the summer of 1999. It is intended as a resource in future discussions of the role that hearing might play in bird avoidance of turbines.

The main body of this report describes hearing measurement in birds, the effects of noise on hearing, and the relationship between avian hearing and the general noise levels around wind turbines. The main body is followed by four appendices. Appendix A is a table organized by species which provides a comprehensive bibliography of the literature on hearing in the quiet (audiograms) in birds, followed by Appendix B which provides plots of the audiograms from 49 species of birds that have been tested to date. Similarly, a bibliography of the literature on how birds hear in noise is given in a table in Appendix C, with corresponding plots of masked auditory thresholds in Appendix D.

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 have exceptionally acute hearing. A considerable amount of work over the past 50 years has repeatedly shown that neither of these notions is true. When hearing is defined as the softest sound that can be heard at different frequencies, birds on average hear less well than many mammals, including humans.

Birds hear best between about 1 and 5 kHz. Acoustic deterrents or “scarecrow” devices are not generally effective because birds habituate to them and eventually ignore them completely. Devices that purport to use sound frequencies outside the hearing range of humans are most certainly inaudible to birds as well because birds have a narrower range of hearing than humans do. A review of the literature on how well birds can hear in noisy (windy) conditions suggests that birds cannot hear the noise from wind turbine blades as well as humans can. In practical terms, a human with normal hearing can probably hear a wind turbine blade twice as far away as can the average bird.

Some wind turbine blades whistle due to blade defects. Depending on the sound level of the whistle produced from a blade defect and the level of the background noise, blade whistles may help birds avoid turbine blades. Because turbine noise and wind noise are predominantly low frequency, almost all the contribution to an overall sound pressure level reading [e.g., 65 dB(A) SPL], comes from frequencies below 1 – 2 kHz. This means that adding an acoustic cue in the region of best hearing for birds (2 – 4 kHz) would add almost nothing to overall sound pressure level but might help birds hear the blades. The existence of blade defects that produce whistles suggests that minor modifications to the acoustic signature of a turbine blade, in the form of whistles, could make blades more audible to birds and at the same time make no measurable contribution to overall noise level.

It is entirely possible, however, that as birds approach a wind turbine, especially under high wind conditions, they lose the ability to see the blade (because of motion smear) before they are close enough to hear the blade. The hypothesis that louder (to birds) blade noises result in fewer fatalities is untested. Making the necessary noise measurements and comparing fatalities at turbines with noticeable whistles with those having no whistles provide one test of this hypothesis.

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Erickson, W., G. Johnson, D. Young, D. Strickland, R. Good, M. Bourassa, K. Bay, and K. Sernka. 2002. Synthesis and Comparison of Baseline Avian and Bat Use, Raptor Nesting and Mortality Information from Proposed and Existing Wind Developments. Report prepared for Bonneville Power Administration. WEST, Inc., Cheyenne, WY.

Primarily due to concerns generated from observed raptor mortality at the Altamont Pass (CA) wind plant, one of the first commercial electricity generating wind plants in the U.S., new proposed wind projects both within and outside of California have received a great deal of scrutiny and environmental review. A large amount of baseline and operational monitoring data have been collected at proposed and existing U.S. wind plants. The primary use of the avian baseline data collected at wind developments has been to estimate the overall project impacts (e.g., very low, low, moderate, and high relative mortality) on birds, especially raptors and sensitive species (e.g., state and federally listed species). In a few cases, these data have also been used for guiding placement of turbines within a project boundary. This new information has strengthened our ability to accurately predict and mitigate impacts from new projects. This report should assist various stakeholders in the interpretation and use of this large information source in evaluating new projects. This report also suggests that the level of baseline data (e.g., avian use data) required to adequately assess expected impacts of some projects may be reduced. This report provides an evaluation of the ability to predict direct impacts on avian resources (primarily raptors and waterfowl/waterbirds) using less than an entire year of baseline avian use data (one season, two seasons, etc.). This evaluation is important because pre-construction wildlife surveys can be one of the most time-consuming aspects of permitting wind power projects.

For baseline data, this study focuses primarily on standardized avian use data usually collected using point count survey methodology and raptor nest survey data. In addition to avian use and raptor nest survey data, other baseline data is usually collected at a proposed project to further quantify potential impacts. These surveys often include vegetation mapping and state or federal sensitive-status wildlife and plant surveys if there is a likelihood of these species occurring in the vicinity of the project area. This report does not address these types of surveys, however, it is assumed in this document that those surveys are conducted when appropriate to help further quantify potential impacts. The amount and extent of ecological baseline data to collect at a wind project should be determined on a case-by-case basis. The decision should use information gained from this report, recent information from new projects (e.g., Stateline OR/WA), existing project site data from agencies and other knowledgeable groups/individuals, public scoping, and results of vegetation and habitat mapping. Other factors that should also be considered include the likelihood of the presence of sensitive species at the site and expected impacts to those species, project size and project layout.

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Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, Jr., K.J. Sernka, and R.E. Good. 2001. Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States. National Wind Coordinating Committee Publication. http://www.nationalwind.org/assets/archive/Avian_Collisions_with_Wind_Turbines_-_A_Summary_of_Existing_Studies_and_Comparisons_to_Other_Sources_of_Avian_Collision_Mortality_in_the_United_States__2001_.pdf

Executive Summary: It has been estimated that from 100 million to well over 1 billion birds are killed annually in the United States due to collisions with human-made structures, including vehicles, buildings and windows, powerlines, communication towers, and wind turbines. Although wind energy is generally considered environmentally friendly (because it generates electricity without emitting air pollutants or greenhouse gases), the potential for avian fatalities has delayed and even significantly contributed to blocking the development of some windplants in the U.S. Given the importance of developing a viable renewable source of energy, the objective of this paper is to put the issue of avian mortality associated with windpower into perspective with other sources of avian collision mortality across the U.S.

We have reviewed reports indicating the following estimated annual avian collision mortality in the United States:

- Vehicles: 60 million - 80 million
- Buildings and Windows: 98 million - 980 million
- Powerlines: tens of thousands - 174 million
- Communication Towers: 4 million - 50 million
- Wind Generation Facilities: 10,000 - 40,000

The large differences in total mortality from these sources are strongly related to the differences in the number (or miles) of structures in each category. There are approximately 4 million miles of road, 4.5 million commercial buildings and 93.5 million houses, 500,000 miles of bulk transmission lines (and an unknown number of miles of distribution lines), 80,000 communication towers and 15,000 commercial wind turbines (by end of 2001) in the U.S. However, even if windplants were quite numerous (e.g., 1 million turbines), they would likely cause no more than a few percent of all collision deaths related to human structures.

There are also other sources that contribute significantly to overall avian mortality. For example, the National Audubon Society estimates avian mortality due to house cats at 100 million birds per year. Pesticide use, oil spills, electrocution, disease, etc. are other significant sources of unintended avian mortality. Due to funding constraints, the scope of this paper is limited to examining only fatalities resulting from collisions with human-made obstacles. Recognize that the cumulative impacts of all mortality factors on birds continue to increase as the human population climbs and resource demands grow. Every effort by all industries to reverse avian mortality trends and minimize the number of bird deaths is important.

Many of the studies of buildings, communication towers, and powerlines were conducted in response to known or perceived problems with avian collisions, and therefore may not be representative of all structures in the United States. As a consequence, using averages of these estimates to project total avian fatalities in the U.S. would be biased high. The estimates provided for the sources of avian mortality listed above, except wind generation facilities, are based on subjective models and are very speculative.

In contrast to other sources of avian collision mortality, avian hazards at most windplants have been evaluated using more standardized methods, and studies have often been conducted without regard to a known or perceived risk. Fatality estimates from wind generation facilities, especially new facilities, have typically considered adjustments for scavenging and observer detection biases. These biases were generally not considered or calculated in studies estimating avian mortality due to collisions with communication towers, vehicles, and buildings and windows. Therefore, the data available to project overall windplant fatalities are generally more accurate than most available data for other collision sources.

Data collected to date indicate an average of 2.19 avian fatalities per turbine per year in the U.S. for all species combined and 0.033 raptor fatalities per turbine per year. Based on current projections of 15,000 operational wind turbines in the U.S. by the end of 2001, the total annual mortality was estimated at approximately 33,000 bird fatalities per year for all species combined. This estimate includes 4,500 house sparrows, European starlings and rock doves, and 488 raptor fatalities per year. We estimate a range of approximately 10,000 to 40,000 bird fatalities. The majority of these fatalities are projected to occur in California where approximately 11,500 operational turbines exist, and most are older smaller turbines (100- to 250-kW machines). Data collected outside California indicate an average of 1.83 avian fatalities per turbine per year, and 0.006 raptor fatalities per turbine per year. Based on current projections of 3,500 operational wind turbines in the U.S. by the end of 2001, excluding California, the total annual mortality was estimated at approximately 6,400 bird fatalities per year for all species combined. This estimate includes 400 house sparrows, European starlings, and rock doves, and 20 raptor fatalities per year. While there have been numerous single mortality events recorded at communication structures that document several hundred avian fatalities in one night, the largest single event reported at a wind generation facility was fourteen nocturnal migrating passerines at two turbines at the Buffalo Ridge, Minnesota, Windplant during spring migration. Based on current estimates, windplant-related avian collision fatalities probably represent from 0.01% to 0.02% (i.e., 1 out of every 5,000 to 10,000 avian fatalities) of the annual avian collision fatalities in the United States. While some may perceive this level of mortality as small, all efforts to reduce avian mortality are important.

Making projections of the potential magnitude of windpower-related avian fatalities is problematic because of the relative youth of the wind industry and the resulting lack of long-term data. For example, of the existing windplants, only the Altamont Pass, Buffalo Ridge and Foote Creek Rim wind resource areas(WRA) have been studied for more than two years, and most of the studies at Altamont focused on raptor mortality. The data collected at Altamont and other older-generation windplants may not be representative of avian mortality of future wind developments. Newer generation windplants incorporate improvements in site planning and changes in the design of the wind turbines. For example, turbines at the Foote Creek Rim Windplant were moved back away from the rim edge because baseline data detected a pattern of raptor use along the edge of the rim (Johnson et al. 2000a). Also, many of the newer generation turbines are designed to provide little perching and no nesting structure (tubular towers, enclosed nacelle). Although it's not clear that perching increases risk of collision, the lack of perching and nesting opportunities may discourage some bird species from using the WRA. Furthermore, some efforts have been made in Altamont to remove turbines associated with higher raptor mortality, and re-powering efforts may result in the replacement of many of the older, smaller turbines with fewer larger, newer generation turbines. If these efforts effectively reduce raptor mortality at Altamont, our raptor mortality projections would also be reduced. Finally, most wind plant developers are required to carry out site evaluations at proposed wind plant sites to determine impacts on birds and other wildlife. While newer generation turbines may be considered more representative of future developments, they have only been in operation in the recent past (i.e. <10 years), and less information on avian collision hazards is available for these turbines.

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Johnson, J.A. 2008. Effects of the Blue Canyon Wind Farm on Avian Populations in Southwest Oklahoma. Preliminary Analysis. Cameron University, Lawton, Oklahoma. 16 pages.

Abstract: The environmental effects of renewable energy development present one of the most significant problems to local planners. Wind power promises to significantly increase the production of energy from renewable sources, but substantial growth in this area may also pose significant potential threats to bird populations. Recent research on this point is ambiguous, and provides little to guide planners. This study analyzes the effects of one case, the Blue Canyon Wind Farm in Southwest Oklahoma, on local avian populations using data from the Audubon Society Christmas Bird Counts and Fish and Wildlife Service Breeding Bird Surveys. This study finds that there are no statistically significant threats from such facilities to regional avian populations. The data suggests the further hypotheses that the effects of wind farms are primarily localized, and that in some circumstances wind farms may actually improve habitat by excluding humans and grazing animals from most of the environment. Key concerns for wind power planning should thus be the adequacy of facility, design careful attention to habitat, and the potential for partnership with rather than conflict between conservation organizations and power companies in the planning process.

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Johnson, G.D. and W.P. Erickson. 2010. Avian, Bat And Habitat Cumulative Impacts Associated With Wind Energy Development In The Columbia Plateau Ecoregion Of Eastern Washington And Oregon. Report prepared for Klickitat County Planning Department. http://www.klickitatcounty.org/planning/filesHtml/200408-EOZ-EIS/Cummulative%20Impacts.pdf.

Abstract: Wind energy development is projected to increase within the Columbia Plateau physiographic region (ecoregion). With this development comes the potential for direct impacts to birds and bats through collision mortality and for indirect effects through habitat fragmentation or displacement of birds and other wildlife. Proposals for wind energy developments are commonly reviewed by natural resource agencies, private conservation groups, permitting authorities and other stakeholders. Frequently, baseline studies are conducted to estimate bird and bat abundance at proposed development sites for use in impact assessments and siting project features, followed by post-construction monitoring studies to measure actual impacts from the wind-energy facility.

With the possible exception of golden eagles (*Aquila chrysaetos*) at the Altamont Pass wind-energy facility, California, where an estimated 40–70 golden eagles are killed each year (Hunt 2002, Smallwood and Thelander 2004), no wind-energy facilities have been documented to cause population declines of any species (Johnson and Stephens 2010). The purpose of this report is to estimate cumulative impacts associated with all existing, permitted, and currently proposed wind-energy facilities within the Columbia Plateau Ecoregion (CPE) of eastern Washington and Oregon. This report updates a previous version (Johnson and Erickson 2008) to account for additional bird and bat fatality estimates from the Leaning Juniper and Klondike III wind energy projects in Oregon, as well as additional raw data on species composition of turbine fatalities from the Goodnoe and White Creek wind energy facilities in Klickitat County, Washington and the Pebble and Hay Canyon wind energy facilities in Oregon. For the purpose of this analysis, we assumed that for cumulative impacts to occur, there must be a potential for a long-term reduction in the size of a population of birds or bats. When assessing the potential for cumulative impacts, it is necessary to first define the population potentially affected by wind energy development. Because birds and other animals do not recognize geopolitical boundaries, we have defined the affected population as those birds and bats of each species that breed, winter, or migrate through the CPE.

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Kerlinger, P. 1996. A Literature Survey of Tower and Wind Turbine Impacts on Birds in the Northeastern United States and the Influence of Ceilometers on Bird Flight. Report prepared for Vermont Department of Public

Service and VERA.
http://www3.digitalfrontier.com/essential_wc5/wind/images/photos/searsburg/kerlinger_july96_2.pdf

Abstract: A small wind power facility has been permitted and is now under construction in Searsburg, Vermond. Eleven turbines standing less than 200 feet in height are being placed on hilltops at about 2800-2900 feet ASL and will generate about 6 mW of power for Green Mountain Power Corporation. Concern by Green Mountain Power Corpostion, the Vermont Department of Public Service, and the National Renewable Energy Laboratory that the turbines may impact birds, causing injury and mortality to migrating songbirds and hawks, and breeding songbirds has resulted in a series of research projects to elucidate the real and potential dangers of the development to birds. The first step in the process is a literature survey, which is the topic of this report.

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Kerlinger, P. and J. Dowdell. 2003. Breeding Bird Survey for the Flat Rock Wind Power Project, Lewis County, New York. Report Prepared for: Atlantic Renewable Energy Corporation. http://www.powernaturally.org/About/documents/FR%20DEIS%20App%20F%20Avian%20Supp%20Rpt%20120303.pdf

Executive Summary: A breeding bird study was conducted at the proposed Flat Rock Wind Power Project in Lewis County, New York. The study was conducted after a project-specific avian risk assessment recommended that such studies be conducted to determine whether federal or New York State listed species or New York State species of special concern were present. The study also focused on determining whether there were likely to be impacts to listed or common species resulting from construction of the wind power project. The object of the study was to identify the species, numbers of individuals, and distribution of those birds in the areas where turbines are being proposed. A total of 49 point counts were established and a GPS location recorded for each point. All point count locations were surveyed three times between June 26 and July 1, 2003, for a period of 5 minutes during which all birds seen or heard were recorded. Also recorded were the distance and direction of each bird from the observer. Surveys were commenced at around 04:45 hours and continued until about 10:00 hours. In addition, a species list was assembled of all birds observed incidental to the point counts. This was done to insure that all species that might nest within the project boundary were found. These incidental surveys were done on the same days as the point counts as well as on three additional days (June 20-22, 2003) while the habitat was assessed and point count locations were established. A total of 78 species were detected at the point count locations and an additional 24 species were detected incidental to the point count survey. No federal or New York State endangered species were detected, although 2 New York State threatened species were found. Eighteen observations of Northern Harriers (threatened) were made during point count surveys and 2 observations of Pied-billed Grebes were observed within the project boundary, but not at any of the point count locations. The former species probably nests in fields within the project boundary and the latter may nest at one of the small ponds on the site. The latter is not likely to nest near any of the turbines because these birds are highly wetland dependent. Two New York State species of special concern, Horned Lark (8 observations) and Vesper Sparrow (8 observations) and it is likely that both species have, at least, 4 nests at the point count locations. These birds are grassland adapted species and are may nest near urbines. The species observed at the point count sites were a mixture of forest (interior and edge), brushland, old field, and grassland birds, as well as a few species that are adapted to farm fields and residential areas. Grassland and forest edge/brushland birds dominated the avifauna. Grassland and old field birds accounted for one-quarter (25.6 %) of all sightings during the study. Bobolinks and Savannah Sparrows accounted for most of these birds (23.1% of all sightings). Mowing of hay was observed at the peak of nesting season and probably eliminates many, if not most, of the active nests during this period. The ten most numerous species are Breeding Birds at the Flat Rock Wind Project, New York – Kerlinger grassland and forest-edge/brushland species, accounting for 61.4% of all birds sightings. The remaining species are primarily forest edge/brushland species. A small proportion of birds found were forest and forest interior species.

It is unlikely that nesting birds will collide with turbines because few spend much time at the altitude of rotors. However, a few species, such as Horned Lark, Vesper Sparrow, and Bobolink, are known to fly high enough at times during aerial displays to potentially collide with turbines and are common among fatality lists at western wind power sites where these birds are very common. It is possible that very small numbers of Northern Harriers and, possibly, American Kestrels may collide with turbines, based on very small numbers of collisions at a few other wind power projects.

The avian community found along Rowsom Road (point counts #91-96) is comprised largely of forest interior species, including several that are thought to be sensitive to fragmentation. Many of these birds were seldom found at other locations within the project site. Impacts resulting from clearing and fragmentation of the Rowsom Road forests may jeopardize the integrity of this forest nesting community. It is possible that turbine construction would extirpate some of the interior forest species and open the forest for edge nesting species, thereby changing the avian community in this area.

Overall, collision impacts are not likely to be biologically significant because the numbers of birds involved is likely to be minimal. Habitat disturbance/displacement impacts to nesting birds will be varied with little impact likely to those nesting in brushland and forest edge and potentially greater disturbance to forest interior nesting birds. With respect to grassland nesting birds, impacts will be localized to the areas within 50-100 m around turbines, as demonstrated in other studies. Although these impacts are not likely to be biologically significant from a regional or global perspective, post-construction studies may be needed quantify these impacts to local populations following construction of the project. The following recommendations were made:

The interior forest habitat along Rowsom Road should be excluded from the project because the birds and habitat there may be severely impacted via forest fragmentation. All permanent meteorology towers should be free-standing, without guy-wires. This will virtually eliminate the potential for collisions with locally nesting birds.
A long-term monitoring study may be initiated that would determine the disturbance/displacement impacts to locally nesting birds. Such a study would examine the abundance and use of grassland nesting songbirds (Bobolinks, Savannah Sparrows, and others) beneath and near turbines to determine the actual area of impact one year following construction, 5 years following construction, and 10 years following construction.

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Mabley, S. and E. Paul. 2007. Critical Literature Review**:** Impact of Wind Energy and Related Human Activities on Grassland and Shrub-Steppe Birds. Prepared for The National Wind Coordinating Collaborative by the Ornithological Council. http://www.nationalwind.org/assets/publications/IMPACTOFWINDENERGYANDRELATEDHUMANACTIVITIESONGRASSLANDANDSHRUB-STEPPEBIRDS.pdf

Abstract: Background and purpose of project: The Grassland and Shrub-Steppe Species Collaborative (GS3C) subcommittee of the Wildlife Working Group of the National Wind Coordinating Collaborative (NWCC), commissioned this critical review of literature. This review pertains to the impacts of wind energy on grassland and shrub-steppe bird species. Its purpose was to examine the actual and potential impacts of wind energy facilities on grassland and shrub-steppe avian species. The impacts included mortality, avoidance, reductions in nesting success and adult survival, and behavioral changes. Commercial wind energy began in the United States in the early 1980s and did not grow appreciably until 1999. Thus, there is relatively little literature, and most comprises site-specific pre-construction wildlife evaluations with post-construction assessments of actual impacts. Studies of sublethal impacts (behavioral responses such as avoidance) are even rarer. The GS3C therefore requested that other anthropogenic activities that are components of or share some common features with wind farms be included, in an attempt to understand potential impacts in the absence of a substantial body of literature. These other activities are roads, urbanization, tall structures (including telecommunications towers and electric transmission lines and stanchions), and oil and gas extraction facilities.

We conducted a comprehensive literature search that included “gray” literature – a wide range of papers, articles, summaries and transcripts of talks, and other materials that did not appear in the peer-reviewed literature – and research from around the world (provided that the paper was available in English). All papers were screened through quality and relevance filters. We considered studies that pertained to grassland or shrub-steppe species or habitats to be relevant. The goal of the quality screening was to focus on well-designed research with adequate sample sizes and sound statistical or qualitative analyses. The selection process was based on the premise that papers of greatest interest would be those from which inferences could be drawn. This aspect of the review was particularly critical because many key questions about human activities have not been studied, or have been studied inadequately. Further, despite some commonalities, the human activities covered by the review were so diverse that only studies that investigated and assigned causation were deemed useful for understanding which components of these activities are of concern in wind energy development. For example, if a study showed that traffic on heavily traveled roads leads to settlement of particulate matter on plants, which destroys food sources or nesting materials or sites, the low level of traffic on roads leading to wind farms is not likely of concern, at least insofar as this particular effect is concerned. In contrast, a paper that shows an effect of weather – such as low cloud cover – on the rate of collisions with obstructions such as telecommunications towers – has implications for any obstruction. Weaknesses in the design or analysis of the papers included in this review are identified and discussed. Some papers have significant weaknesses, but are the best (or only) studies that examined a particular aspect of the activity or behavior of interest.

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Mabey, S. and E. Paul. 2007. Critical Literature Review Impact of Wind Energy and Related Human Activities on Grassland and Shrub-Steppe Birds. Prepared for the National Wind Coordinating Collaborative by the Ornithological Council. The National Wind Coordinating Collabortive, Resolve, Inc., Washington, D.C. 183 pp.

Executive Summary: The Grassland and Shrub-Steppe Species Collaborative (GS3C), a subcommittee of the Wildlife Working Group of the National Wind Coordinating Collaborative (NWCC), commissioned this critical review of literature. This review pertains to the impacts of wind energy on grassland and shrub-steppe bird species. Its purpose was to examine the actual and potential impacts of wind energy facilities on grassland and shrub-steppe avian species. The impacts included mortality, avoidance, reductions in nesting success and adult survival, and behavioral changes. Commercial wind energy began in the United States in the early 1980s and did not grow appreciably until 1999. Thus, there is relatively little literature, and most comprises site-specific pre-construction wildlife evaluations with post-construction assessments of actual impacts. Studies of sublethal impacts (behavioral responses such as avoidance) are even rarer. The GS3C therefore requested that other anthropogenic activities that are components of or share some common features with wind farms be included, in an attempt to understand potential impacts in the absence of a substantial body of literature. These other activities are roads, urbanization, tall structures (including telecommunications towers and electric transmission lines and stanchions), and oil and gas extraction facilities.

We conducted a comprehensive literature search that included "gray" literature – a wide range of papers, articles, summaries and transcripts of talks, and other materials that did not appear in the peer-reviewed literature – and research from around the world (provided that the paper was available in English). All papers were screened through quality and relevance filters. We considered studies that pertained to grassland or shrub-steppe species or habitats to be relevant. The goal of the quality screening was to focus on well-designed research with adequate sample sizes and sound statistical or qualitative analyses. The selection process was based on the premise that papers of greatest interest would be those from which inferences could be drawn. This aspect of the review was particularly critical because many key questions about human activities have not been studied, or have been studied inadequately. Further, despite some commonalities, the human activities covered by the review were so diverse that only studies that investigated and assigned causation were deemed useful for understanding which components of these activities are of concern in wind energy development. For example, if a study showed that traffic on heavily traveled roads leads to settlement of particulate matter on plants, which destroys food sources or nesting materials or sites, the low level of traffic on roads leading to wind farms is not likely of concern, at least insofar as this particular effect is concerned. In contrast, a paper that shows an effect of weather – such as low cloud cover – on the rate of collisions with obstructions such as telecommunications towers – has implications for any obstruction. Weaknesses in the design or analysis of the papers included in this review are identified and discussed. Some papers have significant weaknesses, but are the best (or only) studies that examined a particular aspect of the activity or behavior of interest.

Wind energy: Mortality caused by wind energy development has been more frequently studied than have other impacts, and the studies are site specific. We found no landscape-level or regional studies of mortality, although combined fatality data from multiple independent studies in three regions of the country in which the study sites include some grassland or grassland-like habitat suggest that the lowest rate of mortality per megawatt of energy generated was 2.7 birds and the highest was 3.5 birds per megawatt. The lack of broader studies may be a function of the fact that studies of wind energy impacts tend to be initiated at the behest of regulatory agencies that respond to public concern or opposition, or by wind energy developers who seek to answer more general concerns about the impacts of wind energy. Studies have followed the development of the industry; thus, studies of Midwestern sites, which often include grassland sites, are fairly common. However, site variation made generalizing from the results difficult. Mortality appeared to be more strongly associated with migration than with local use of the area, although 30% of fatalities were resident or breeding birds. Passerines comprised 82% of the mortalities across nine sites. Few studies reported on the relative abundance of species at a site, and little inference could be drawn from the data. From the few papers that reported behavioral impacts, interesting and useful – but somewhat contradictory – observations emerged. Birds avoided areas with turbines, and although most flew below rotor height, those flying within the span of the rotors adjusted their flight patterns to avoid the spinning blades. Another study determined that configuration of the wind farm affected avoidance behavior, as did distance to other anthropogenic features. Birds stayed farther from strings than from clusters; the overall loss of foraging habitat caused by avoidance was three times greater than the loss of foraging area. Site characteristics such as wind speed and terrain affected the birds' ability to avoid turbines, particularly if they entered the turbine area from below the turbines. In this particular study, there was no evidence that birds actively avoided the turbines. Population-level impacts were difficult to assess, because there were so few papers, and they were not representative of all landscape and habitat types. The results of papers reviewed here were inconsistent. Two showed a reduction in breeding populations (passerines and raptors), whereas two others found no effect. However, the designs were such that the ability to detect a true difference was weak. One study showed a marked difference in species abundance at control plots, as well as increased species richness, but little difference in community composition. Of particular interest is that avian density did not increase when turbines were turned off. In a second study, no raptors nested in a wind plant area, compared to 5.94 nests per 100 km2 in the surrounding area, which comprised similar habitat. However, the wind plant area would have otherwise been expected to support only two nests, so the finding might not have been significant. The results of a third study were mixed in that density of nonbreeding birds differed significantly from year to year and between the wind farms and the control sites, whereas the density of breeding birds was not significantly different between the sites. At an Oklahoma wind facility, nine of 22 breeding bird species (but only three grassland bird species) showed significant differences in density as distance from the turbines increased. Nine grassland bird species showed no difference in density as a function of distance. However, sample size was low and statistical power (ability to detect a difference) was probably inadequate.

Roads: Roads are key components of all the human activities included in this review. The papers discussed in this section assessed the edge effect of roads through grasslands, the quality of roadside habitat, and disturbance resulting from traffic. We found few studies of road-related mortality that focused specifically on grassland or shrub-steppe bird species. Behavioral impacts associated with edge effects were mixed, and none of the studies isolated the mechanism or mechanisms, other than noise and predation, responsible for observed effects. Loggerhead Shrikes, which are predatory, preferred nesting territories with road fence lines, probably as vantage points to spot prey, but nesting success was significantly lower than that at sites away from the fence lines. No statistical relationship between roads and nest success was found for Mallard, Gadwall, or Blue-winged Teal. Along two-lane roads bordered by agricultural land on one side and grassland on the other, Bobolink density increased as distance from edge increased, though forest edge had a greater impact than road or agricultural edge. Another study of Bobolinks found a very strong roadside edge effect up to 50 m from the road edge, although daily survival rates did not vary with distance from edge. In a recent study of the response of Lesser Prairie-Chickens to various human activities, unimproved roads had no effect on distance to nests, but only buildings had a greater impact than improved roads; nest distance averaged 859 yards from the road. For Red-winged Blackbirds, density and productivity were significantly lower – even to the extent that they constituted population sinks – along roadsides. In that study, predation was the only causal factor that explained this result. Abundance for five of eight grassland bird species was significantly lower along roads with drainage ditches and fences and planted with a non-native species than along trails (a trail is defined as a road with a single pair of wheel ruts). However, in agricultural areas where roadside vegetation was the only remaining natural grassland habitat, 10 grassland species used the habitat. Even if nesting density along roads was high, a predation rate of 52%, combined with mowing and cowbird parasitism, resulted in productivity that was no higher than that of the nearby agricultural fields. A study of managed and unmanaged roadside verges along roads with varying traffic intensity found no consistent correlations between nest density (or nest success) and road type or traffic volume. In fact, nest densities were highest along the busiest road. However, an experimental study that used artificial nests showed that road type and habitat adjacent to roadside habitat had no effect on predation rate, whereas roadside habitat and nest position (nests on backslopes) in that habitat were significant factors. Fences resulted in much higher predation rates. Noise has been studied as one cause of the observed avoidance of roads, but the effect seems to vary with species. Studies of urban roads with significant traffic volume (5,000 to 850,000 vehicles per day) have been a major focus in the Netherlands. At lower traffic volumes, noise accounted for a reduction of more than 10% in density of seven species within 100 m of roads; higher traffic volumes resulted in a reduction of 40% in density of all 12 species studied within 100 m of roads. Yet another study that examined the effect of traffic volume found that low traffic volumes (3,000 to 8,000 vehicles per day) had no effect on the abundance of grassland bird distributions, although density within that range varied with patch size. At moderate volumes (8,000 to 15,000 vehicles per day), roads reduced breeding bird density within 400 m but had otherwise no effect on the distribution of grassland birds. At heavier traffic levels (15,000 to 30,000 vehicles per day), roads affected presence and breeding density to a distance of 700 m. At the heaviest traffic volumes (30,000 or more vehicles per day), road effects extended to 1,200 m. In Denmark, the avoidance of roads by Pink-footed Geese reduced available foraging habitat by 21% near large roads and 10% near small roads. Observations of a variety of human disturbances in the landscape led to the conclusion that wind turbines and other disturbances should be clustered or overlapped to minimize overall impact on habitat availability. In contrast, Barnacle Geese were unaffected by roads. No significant difference was found in grazing intensity regardless of the distance from the road. Avian mortality from automobile collisions may be a function of the suitability of adjacent habitat for prey species. Barn Owls and Long-eared Owls suffered the greatest mortality near grain fields that were ideal habitat for voles and on roads that were at the same elevation as the surrounding habitat.

Urbanization: Urbanization entails a broad loss and degradation of habitat. Few studies of the impacts of urbanization on grassland and shrub-steppe species were found; the eight reviewed here document changes in bird species composition, richness, and abundance in relation to density of urban features. As wind farms are generally sited in open areas, the findings pertinent to urbanization may have limited relevance. The impact of the growth of Tulsa, Oklahoma, from 1967 to 1991 was studied by contrasting two sites – a "low-density" rural area and a "high-density" rural area. Some species declined in both landscapes, others in only one landscape, and others did not change in either landscape. Protected grassland in an urbanizing area (Boulder, Colorado) maintained populations of 22 of 29 grassland bird species for nearly a century; however, four of these species declined significantly in Boulder County; the other seven disappeared entirely from the Boulder area. One of two raptor species in the same area declined significantly, but not until the latter half of the 40-year period of human growth, which suggests a possible threshold effect. The other species increased significantly and were found more commonly in the more densely developed areas. That same Boulder Open Space served as the setting for a study about the impacts of urbanization on grassland songbirds. Declines in songbird populations were determined to be significantly affected by the quality of the habitat; severe declines occurred when urban cover types in the 40-ha landscape area constituted more than 5% of the land cover. A similar result was seen in Sweden, where species richness declined in proportion to the extent of urban elements in the landscape. Urbanization seemed to influence the life history traits of two populations of Lesser Prairie-Chickens. Higher female survival and lower reproductive effort (few renesting attempts 10 within a single season) were observed in a population residing in an area with large open parcels and few fences, roads, or power lines. The other population suffered reduced female survival and higher reproductive effort, which resulted in population instability. A reduction in vertebrate abundance in suburban areas (versus protected areas) was thought to cause partial brood loss in a suburban Florida Scrub Jay population because the last hatched chicks starved. However, the results of this study suggest that starvation might result not from inadequate vertebrate abundance, but from the relative paucity of nest helpers, a prominent feature of Florida Scrub Jay behavior that involves younger, nonreproductive birds helping older birds to raise broods.

Tall structures: Budget and time constraints prevented us from reviewing the more than 1,000 papers in this category. However, earlier reviews of much of this literature led us to believe that most would not meet the quality criteria we had established. Much of it was purely observational and inadequately reported important variables. As the description of habitat was often lacking and many papers primarily reported species identification and counts of dead birds, identifying papers on grassland and shrub-steppe species would be extremely difficult. Therefore, a more general discussion is provided here to identify variables that might provide insight into causal mechanisms. Mortality estimates for tall structures generally span orders of magnitude for any particular kind of structure. These estimates are based on biased observations, as per-structure estimates are often based on mass mortality events or nonrandom monitoring of structures that are suspected of causing mortality. If little or no mortality is observed, monitoring stops and the observations are not reported. There have been no randomized, landscape-level monitoring efforts. These per-structure estimates are then multiplied by the number of individual structures of a particular type, even though those estimates are probably not typical of the mortality rates for structures in that category. In addition, many studies result from regulatory inquiry into site specific applications and employ the Before-After/Control-Impact (BACI) methodology, which, in the case of wind energy studies to date, comprised assessments of species composition and abundance before and after construction at construction and reference sites, but have not assessed mortality or changes in mortality rates. Positive associations have been found between the incidence of avian collisions with telecommunications towers and structure height, lighting, and weather conditions (primarily fog, cold fronts, and storms). Numerous observers have reported nonlinear flight (e.g., circling behavior) around towers with lights, but the specific attributes of light – color, lighting type (steady versus flash, incandescent versus strobe) – have not been studied experimentally until very recently, and these data have not yet been published. Earlier reports about the impacts of light color and type are conflicting. Extinguishing the lights in buildings has been documented to reduce mortality, but as lights associated with tall structures tend to be aviation warning lights, this is not an option.

Oil and gas extraction: Elements of this activity overlap other categories discussed in this review, including roads and power lines. The analysis here focused on avoidance and other behavioral responses to oil and gas wells, though referenced studies focused on various elements of these features, including noise, physical motion, associated structures such as pipelines, roads (as a type of habitat fragmentation and with regard to traffic), and habitat change that promotes the establishment of new pathogens into the environment. Avian population changes resulted primarily from avoidance rather than mortality; the loss of usable habitat resulted in population reductions. Most studies we examined involved shrub-steppe species; some discuss the impacts on grassland passerines. Assessments of avoidance are more common than are studies that identify specific components associated with that avoidance. Retaining ponds that hold water pumped from coal beds that are in the process of extracting methane are ideal breeding grounds for the mosquito species that transmit West Nile Virus. The potential impact on sage-grouse and other species found in these areas is being evaluated. The water in these ponds may also be contaminated with petroleum and heavy metals, but the impact on birds has not been studied. Some species do not avoid oil and gas wells. Prairie Falcons seemed unaffected, regardless of the density of wells, although they nested at some distance and reacted to blasting noise by flushing from nests or sitting upright. Strong declines in sage-grouse populations in Alberta and Colorado have been amply documented, but the association with oil and gas development is weak because that development began at least two decades before population counts began. Sage-grouse will locate in or near oil fields if suitable habitat is available and if they can avoid paved roads and oil structures. However, power lines associated with oil and gas fields may lead to increased raptor predation and, in turn, lower population growth rates. Leks at a greater distance from compressor stations had more birds than did leks nearer to the stations, but whether this was due to the noise emanating from the compressor, roads, traffic, or habitat loss is not clear. Increased mortality of males at leks and a reduction in female population growth have also been attributed to wells. The impact of proximity to wells was significant – the negative impact was observed to a distance of 4.7 km for producing wells and 6.2 km for drilling rigs. Two major studies of the impacts of oil and gas wells on sage-grouse were published in the past two years. The first comprehensive study examined relationships between breeding success and adult life history traits with numerous habitat conditions, including vegetation structure and composition, wetness (a measure of soil or surface moisture content derived from remotely sensed data), distance to wells, and other human activities such as roads. Chick and adult male mortality increased closer to wells and with increased well density. Male attendance at lek sites decreased closer to wells and with increased traffic volume, and in areas with high densities of wells. Females chose nest sites nearer to wells than would be expected by random distribution, but avoided areas with higher well density. Broods were also closer to wells than would be expected in a random distribution, but chick mortality increased closer to wells and with increased well density. In contrast, female sage-grouse that visited leks disturbed by wells established nest sites farther from those leks than did females that visited undisturbed lek sites. Results with Lesser Prairie-Chickens were mixed: all nests at two sites were at a greater distance from wells than would be predicted by random distribution. At one site, the difference in distances for all nests was statistically significant. However, at the other site, the difference in distances was not statistically significant for any of the nests. A model of the relationship between distance to wells from sage-grouse nests, as well as 12 vegetation variables, predicted nest success 74.6% of the time. Another model combined two separate models for probability of use and habitat-associated risk for Greater Sage-Grouse. It was based on five vegetation characteristics and one parameter that combined all human activities in the area, which is called "edge," though it does not actually measure distance to habitat edge. The model identified source habitat and attractive sink habitat (which has suitable vegetation characteristics but is also high risk) with 65% success in predicting nest location and 71% success in predicting brood location. Traffic volume along roads associated with oil and gas wells affected sagebrush obligates such as Brewer's Sparrow, Sage Thrasher, and Sage Sparrow. Declines of 60% were observed within 100 m of roads with higher traffic volumes (697 vehicles per day) compared to roads with lower volume (fewer than 344 vehicles per day). However, there was no observed difference in abundance within 100 m of pipelines and from 100 m to 200 m of pipelines.

Emergent questions and research needs: Though the body of literature is large, there are few well-designed studies with adequate sample sizes for all activities included in this review. However, the studies discussed here suggest hypotheses for further testing. Careful designs are needed to assess causation with regard to mortality and behavioral responses. Three design flaws were common to most of the studies reviewed here: (1) small sample size; (2) inappropriate sampling scale (temporal, spatial, or both); and (3) poorly described or controlled reference sites. Most studies lacked replicates. Some failed to adequately describe the habitat type and other habitat characteristics; few quantified those variables. Baseline studies of pre-impact conditions are almost universally lacking, although BACI studies are recommended for wind energy facilities by the NWCC Wildlife Workgroup, and are sometimes undertaken. Also needed are multi-site, landscape-level studies that use stratified random samples to distinguish between the various attributes of activities that are thought to have negative impacts on avian behavior and survival. These large-scale studies will also result in much better mortality estimates, which will be useful for determining the needed level of mitigation and other conservation responses.

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Morrison, M.L. 2006. Bird Movements and Behaviors in the Gulf Coast Region: Relation to Potential Wind Energy Developments. National Renewable Energy Laboratory NREL/SR-500-39572, Golden, CO. http://www.nrel.gov/wind/pdfs/39572.pdf

Introduction: The United States has high-energy demands that are for the most part satisfied by the fossil fuel industries. Fossil fuel is a finite resource that will only become more valuable as supplies inevitably become more limited and as demand increases. Wind-generated energy may represent an alternative to fossil fuels for meeting electricity needs because harnessing wind energy does not generate the pollutants that burning fossil fuels produces. Furthermore, other than constructing the facility and supporting infrastructure, ecological communities are not disturbed to the same extent as occurs when coal deposits are extracted from the earth.

Nevertheless, wind-energy facilities do impact natural resources. Although an individual wind turbine has a small footprint, wind farms consisting of dozens to hundreds or more turbines can cover hundreds to thousands of acres. The infrastructure required to install and maintain turbines in a wind farm can directly damage sensitive ecological communities through road building, clearing of tower pads, maintenance buildings, and electrical distribution lines. The presence of vehicles and personnel in wind farms may indirectly impact environmental resources through disturbance. So there is the risk of negatively impacting plant and animal communities associated with establishing financially viable wind farms. However, the primary concern associated with constructing wind farms may be the impacts that wind turbines might have on birds and bats.

The purpose of this paper is to discuss the possible impacts of wind development to birds along the lower Gulf Coast, including both proposed near-shore and off-shore developments. I do this by summarizing wind resources in Texas, discussing the timing and magnitude of bird migration as it relates to wind development, reviewing research that has been conducted throughout the world on near- and off-shore developments, and providing recommendations for research that will help guide wind development that minimizes negative impacts to birds and other wildlife resources.

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National Research Council. 2007. Environmental Impacts of Wind Energy Projects. Report prepared for the Council on Environmental Quality. The National Academic Press. Washington, D.C. 376 pp.

Ecological Impacts: Wind turbines cause fatalities of birds and bats through collision, most likely with the turbine blades. Species differ in their vulnerability to collision, in the likelihood that fatalities will have large-scale cumulative impacts on biotic communities, and in the extent to which their fatalities are discovered. Probabilities of fatality are a function of both abundance and behavioral characteristics of species. Among bird species, nocturnal, migrating passerines3 are the most common fatalities at wind-energy facilities, probably due to their abundance, although numerous raptor fatalities have been reported, and raptors may be most vulnerable, particularly in the western United States. Among bats, migratory tree- roosting species appear to be the most susceptible. However, the number of fatalities must be considered in relation to the characteristics of the species. For example, fatalities probably have greater detrimental effects on bat and raptor populations than on most bird populations because of the characteristically long life spans and low reproductive rates of bats and raptors and because of the relatively low abundance of raptors. The type of turbines may influence bird and bat fatalities. Newer, larger turbines appear to cause fewer raptor fatalities than smaller turbines common at the older wind-energy facilities in California, although this observation needs further comparative study to better account for such factors as site-specific differences in raptor abundance and behavior. However, the data are inadequate to assess relative risk to passerines and other small birds. It is possible that as turbines become larger and reach higher, the risk to the more abundant bats and nocturnally migrating passerines at these altitudes will increase. Determining the effect of turbine size on avian risk will require more data from direct comparison of fatalities from a range of turbine types. The location of turbines within a region or landscape influences fatalities. Turbines placed on ridges, as many are in the MAH, appear to have a higher probability of causing bat fatalities than those at many other sites. The overall importance of turbine-related deaths for bird populations is unclear. Collisions with wind turbines represent one element of the cumulative anthropogenic impacts on these populations; other impacts include collisions with other structures and vehicles, and other sources of mortality. As discussed in Chapter 3, those other sources kill many more birds than wind turbines, even though precise data on total bird deaths caused by most of these anthropogenic sources are sparser and less reliable than one would wish. Chapter 3 also makes clear that any assessment of the importance of a source of bird mortality requires information and understanding about the species affected and the likely consequences for local populations of those species. The construction and maintenance of wind-energy facilities also alter ecosystem structure through vegetation clearing, soil disruption and potential for erosion, and noise. Alteration of vegetation, including forest clearing, represents perhaps the most significant potential change through fragmentation and loss of habitat for some species. Such alteration of vegetation is particularly important for forest-dependent species in the MAH. Changes in forest structure and the creation of openings alter microclimate and increase the amount of forest edge. Plants and animals throughout an ecosystem respond differently to these changes. There might also be important interactions between habitat alteration and the risk of fatalities, such as bat foraging behavior near turbines.

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Thelander, C.G. and L. Rugge. 2000. Avian Risk Behavior and Fatalities at the Altamont Wind Resource Area. March 1998 to February 1999. National Renewable Energy Laboratory Report. http://www.batsandwind.org/pdf/ThelanderandRugge_2000.pdf

Introduction: Wind energy development in the Altamont Pass region of California peaked during the mid-1980s, when most of the wind turbine towers now in existence were erected (Hunt 1997). Since 1981, more than 7,000 wind turbines have been installed in the Altamont Wind Resource Area (WRA). Currently about 5,000 are operating, with that number being reduced as repowering continues. They are distributed over an area of approximately 150 km2 (Walcott 1995).

In the Altamont WRA, wind speeds average 25.45 km/hr between April and September, when the facility produces 70% to 80% of its power. During winter, the wind speeds drop to 15.25 km/hr. In the summer months, wind speeds are generally sufficient to operate the turbines by mid-afternoon and well into the evening hours. Since about 1989, several university and private research groups have conducted research on bird interactions with various turbine and tower configurations in the Altamont WRA. Most of these early studies focused on quantifying fatalities and calculating mortality rates for highly vulnerable bird species, specifically raptors.

Although it has long been documented that wind turbines kill birds, especially predator species (i.e., raptors), little is known about specific flight and perching behaviors near wind turbines. What behaviors cause birds to be struck by turbine blades? Can these factors be predicted or quantified in such a way that future wind energy facilitates can be designed to avoid or minimize them? Bird fatalities, and how to minimize them, often are a major licensing consideration for any wind energy facility.s proponents and for the regulatory agencies responsible for conserving natural resources.

In March 1998, the National Renewable Energy Laboratory (NREL) started a research project designed to address behavior factors that contribute to turbine mortalities. Previously researchers had not attempted to correlate bird flight and perching behaviors with fatality data for the same period and at the same turbines. This approach is the central focus of this project. This report is intended solely as a progress report. The five tables and three figures referenced in the text appear in a separate section at the end of the report. The findings presented here should be considered preliminary ones. A comprehensive report is scheduled for the end of Phase II.

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Thelander, C.G., K.S. Smallwood, and L. Rugge. 2003. Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area. Period of Performance: March 1998–December 2000. National Renewable Energy Laboratory Report. http://www.nrel.gov/wind/pdfs/33829.pdf

Executive Summary: It has been documented that wind turbine operations at the Altamont Pass Wind Resource Area kill large numbers of birds of multiple species, including raptors. We initiated a study that integrates research on bird behaviors, raptor prey availability, turbine design, inter-turbine distribution, landscape attributes, and range management practices to explain the variation in avian mortality at two levels of analysis: the turbine and the string of turbines. We found that inter-specific differences in intensities of use of airspace within close proximity did not explain the variation in mortality among species. Some species, however, spent more time flying within 50 m of turbines than expected based on the area within this proximity zone, and they spent less time within 51-100 m or 101-300 m, indicating that these species were drawn into the lands near turbines for some reason(s).

Unique suites of attributes relate to mortality of each species, so species-specific analyses are required to understand the factors that underlie turbine-caused fatalities. We found that golden eagles are killed by turbines located in the canyons and that rock piles produced during preparation of the wind tower laydown areas related positively to eagle mortality, perhaps due to the use of these rock piles as cover by desert cottontails. The degree of clustering of pocket gophers around wind towers related positively to red-tailed hawk mortality, and the degree of clustering of gophers appeared to be greatest on steeper slopes into which laydown areas and access roads were cut, thereby producing increased lateral and vertical edge (which gophers prefer for constructing their burrow systems).

Tubular towers killed more red-tailed hawks and other raptors than would be expected from their numbers within our study area, and this pattern was even stronger for areas in which the tubular towers occurred on ridge tops and other landscape features that produced strong declivity winds. Rotor speed correlated positively with mortality, as did rotor height above the ground and rotor diameter. The windswept area of the turbine string, meaning the cumulative rotor-swept areas of all turbines in the string, correlated positively with mortality of several avian species. Factoring in the windswept area eliminated the effect of turbine position in the string, which some had thought to be an important factor for avian mortality, and which was verified by our data prior to factoring in the windswept area. Raptor fatalities did not correspond well with the distribution of California ground squirrels. Other similar relationships between fatalities and environmental factors are identified and discussed. The tasks remaining to complete the project are summarized.

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Whitfield, D.P. and M. Madders. 2006. A review of the impacts of wind farms on hen harriers *Circus cyaneus* and an estimation of collision avoidance rates. Natural Research Information Note 1 (revised). Natural Research Ltd, Banchory, UK.

Abstract: Assessment of the impacts of proposed wind farms on hen harriers is often hampered by an apparent paucity of available information from studies of impacts at operational wind farms. To a large degree this is because few studies are readily or obviously accessible, and so the purpose of this review was to utilise those studies which could be accessed (primarily reports posted on websites) to examine the evidence for the susceptibility of hen harriers to the two main impacts of terrestrial wind farms on birds: displacement/disturbance and fatality through collision with rotating turbine blades.

At least eight studies of hen harrier displacement effects have been conducted, using several study designs, in USA and continental Europe. Only one study documented good evidence of displacement and it was reasonable to conclude that although further studies are highly desirable, if displacement of foraging occurs then it will likely be limited to within 100 m of wind turbines if it occurs at all. In keeping with most other studies of raptor displacement, therefore, it appears that foraging hen harriers have a low sensitivity to disturbance at operational wind farms. Persecution of some UK hen harriers may make such populations more susceptible to disturbance, however. Displacement impacts on nest site selection are more poorly studied, and preliminary results from Scotland and Northern Ireland indicate that birds will nest 200 – 300 m from turbines.

At least 10 wind farms where hen harriers occur have been subject to research on collision fatalities. Deaths were recorded at three sites with only a single study, involving searches over 7,500 turbine-years, recording more than one casualty, and no collision victims were recorded at seven sites. Against expectations, documented mortality was not positively related to harrier activity since wind farms with recorded deaths were those with the lowest harrier activity levels. The cause of this apparently counter-intuitive result was not obvious, with the height of rotor blades (since harriers typically fly at low altitudes) and an index of risk exposure not offering satisfactory explanations. It was apparent, nevertheless, that hen harriers do not appear to be susceptible to colliding with turbine blades and that collision mortality should rarely be a serious concern.

Collision risk modelling under the Band Collision Risk Model (CRM) (Band et al. 2006) can be used to estimate predicted mortality rates at proposed wind farms. Avoidance rates under the Band model (the extent to which birds avoid colliding with rotor blades) were estimated from eight wind farms in USA: estimates were 100% (at six sites), c. 99.8% (at one site) and 93.2% (at one site). For the six sites with 100% avoidance, harrier activity levels were relatively high so this could not explain the absence of any fatalities and at two of these sites searches were conducted at 50 to 150 turbines over several years. At the remaining four sites with no fatalities a combined 101 turbines were searched for four years in total. All eight studies accounted for search biases due to observer efficiency and corpse removal. Thus, there was no evidence of any deficiencies in the methods employed at the sites where avoidance was 100%. It is suggested that harrier collisions are relatively rare events and probably subject to stochastic or accidental conditions and hence sampling may produce occasional relatively low avoidance rate estimates while most estimates are substantially higher. Unbiased estimates may therefore require studies at a substantial scale and duration which are probably impractical and difficult to justify cost-effectively. Combining results from several smaller scale studies may thus provide an appropriate solution and for the 'non-Altamont' USA studies a 99% avoidance rate predicted a combined number of harrier fatalities very close to the empirical measure. In conclusion, an assumption of 95% avoidance is likely to be overly cautious and an avoidance rate of 99% appears to be more realistic.

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Wyoming Game and Fish Department. October 2009. Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat. http://gf.state.wy.us/downloads/pdf/Finalpublicwindenergyrecommendtaionsdraft10.pdf

The major purposes of this document are to provide recommendations for collecting baseline data, subsequent monitoring and mitigating documented impacts of affected wildlife due to the development of wind energy in Wyoming. These recommendations apply to all lands within the state. The document provides guidance under the Wyoming Game and Fish Commission's (WGFC) Mitigation Policy (WGFC 2008) and supports the WGFC's Mission of "Conserving Wildlife – Serving People."

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Young, Jr., D.P., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Avian and Bat Mortality Associated with the Initial Phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming (November 1998 - June 2002). Report prepared for Pacificorp, Inc., Portland, Oregon; SeaWest Windpower Inc., San Diego, California; and Bureau of Land Management. http://www.west-inc.com/reports/fcr_final_mortality.pdf.

Introduction: An estimated 100 million to 1 billion birds die annually in the United States by colliding with manmade objects (Klem 1991). Although generally considered environmentally friendly, windpower, at most locations, has been associated with avian fatalities caused by collisions with turbines and other wind plant structures (e.g., Orloff 1992, Erickson *et al*. 2000, Erickson *et al*. 2001, Johnson *et al*. 2002). Studies conducted to date indicate that raptors and passerines appear to be the most susceptible to turbine collisions in the U.S. (AWEA 1995). At a few specific locations, such as the Altamont Pass Wind Resource Area (WRA) near Livermore, California, there have been higher levels of raptor fatalities than at other wind facilities (Orloff and Flannery 1992). However, in comparison to TV/radio and other communications towers, the number of bird mortalities in wind power facilities is thought to be relatively small (AWEA 1995, Erickson *et al.* 2001). TV/radio towers often result in episodic mortality events that may result in thousands of dead birds when inclement weather occurs during migration periods (Avery et al. 1980, Trapp 1998, Kemper 2000). Based on wind development in operation at the end of 2001, it has been estimated that wind turbines cause 0.01 to 0.02 percent (1-2 of every 10,000 fatalities) of collision-caused bird mortality in the U.S. (Erickson *et al.* 2001). Early wind energy facilities in the U.S., such as those in the Altamont Pass, were placed without regard to factors such as avian use, and some of these sites are located where birds are abundant and the risk of turbine collisions is high (AWEA 1995). As a result, higher levels of raptor mortality have been reported there than at other wind facilities. In the Altamont Pass area, where more than 5,000 turbines exist within the WRA, Orloff and Flannery (1992) estimated 567 raptors were killed over a 2-year period from colliding with turbines. Researchers estimated 6,800 birds, primarily passerines, were killed annually at the San Gorgonio, California wind facility based on 40 dead birds found while monitoring nocturnal migrants (McCrary *et al.* 1986). The 40 dead birds were comprised of 15 passerines, seven waterfowl, two shorebirds, and one raptor. Because most of these birds were passerines and large numbers of passerines migrate through this area, it was concluded that this level of mortality was not biologically significant (Southern California Edison Company, unpublished data). Studies conducted on other wind generation facilities have not detected these levels of mortality (e.g., Erickson *et al.* 2000, Young *et al.* 2001, Johnson *et al.* 2002), and numerous factors including avian abundance, species composition, geographic area, landscape features, prey abundance, and wind plant features are believed to influence the potential for and level of avian mortality (Nelson and Curry 1995, Orloff 1992, Erickson *et al.* 2000). Although avian mortality associated with windpower development has been of primary concern, recent studies have found that bat mortality also occurs at wind plants. Bat mortality at wind plants was first documented in Australia (Hall and Richards 1972). At a 107.25 MW wind plant on Buffalo Ridge, Minnesota, 184 dead bats were found over a four year period (Johnson *et al*. 2002). Bat mortality has also been documented at wind plants in California (Howell 1997), Oregon (Erickson *et al*. 2000), Wisconsin (Steve Ugoretz, Wisconsin DNR, pers. comm.), Colorado (Ron Ryder, Colorado State University, pers. comm.), and Wyoming (Young *et al.* 2001).

In December 1998, SeaWest completed development of a 41.4 megawatt (MW) wind plant on Foote Creek Rim (FCR) in Carbon County, Wyoming. This initial construction phase of the Foote Creek Rim wind plant (hereafter referred to as FCR I) is comprised of 69 600-kilowatt Mitsubishi turbines (41.4 MW capacity) and related facilities, including distribution lines, five meteorological (met) towers, communication system, transformers, substation, roads, and operations and maintenance facilities. Formal carcass searches to locate dead birds and bats were initiated at all turbines in November 1998, when approximately 25% of the turbines became operational. The balance of the turbines became operational shortly thereafter. This report presents results of approximately 3.5 years (November 3, 1998 to June 5, 2002) of carcass search studies for FCR I (Turbines 1-69 and associated met towers). Subsequent construction phases II and III (FCR II, FCR III) of the wind plant development on FCR are the subject of a comparable study funded by the National Renewable Energy Laboratory (NREL) and SeaWest Windpower, Inc. Fatality searches for construction phases II -IV were initiated following completion and start-up of each phase: July 1999 for FCR II and FCR III; and November 2000 for FCR IV. Results of these additional studies are partially reported in Young *et al.* 2002.

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Suarez, M., P. Heglund, R. Kratt, and E. Kirsch, 2008. A Landscape Scale Decision Support Tool forMonitoring Bird and Bat Migration AcrossWisconsin. Public Service Commission of Wisconsin and the Statewide Energy Efficiency and Renewables Administration Environmental and Economic Research and Development Program. Final Report. http://www.focusonenergy.com/files/Document_Management_System/Environmental_Research/heglundmigration_report.pdf

Abstract: Migratory birds and bats face many challenges as they traverse the airspace between wintering and breeding grounds. Among these challenges are tall structures, including wind turbines and communication towers that are being erected or proposed across the United States and off shore. Complicating factors include the knowledge that birds and bats migrate at night and are therefore very difficult to track over long distances. In particular, neotropical migrant birds and bats tend to have small body sizes and therefore are too small to wear radio transmitters with enough capacity to monitor for long distances and long periods of time. Indeed, few tools exist for deciphering the migratory habits of volant species, but incorporating the use of radar to better understand migration movements and habitat use patterns, holds promise. Nexrad Weather Surveillance Radar (WSR-88D) is increasingly viewed as a potentially valuable resource in the study of bird and bat migration (Gauthreaux and Belser 1998b, 2003; Diehl et al. 2003; Diehl and Larkin 2005). The NOAA National Climatic Data Center (NCDC) archives WSR-88D data and makes it freely available through their website. We captured 6 years of data from the Nexrad WSR-88D sites located in Wisconsin (and in neighboring states) by generating time-series mosaics of the radar products. The animations allow the viewer to identify and summarize timing, stop over locations, and general pathways of movement across Wisconsin where Nexrad coverage exists. Only by understanding the behavior and phenology of migrating birds and bats can we hope to minimize the impact of wind power generation projects on those populations. We are providing Wisconsin resource managers with a tool to help them better understand where and when large numbers of birds and bats are most vulnerable to development and operation of wind power generators. With this tool, managers can then better target site specific evaluations as individual projects arise as well as work preemptively with industry managers to select or avoid specific sites for future projects. Perhaps most importantly, managers and scientists can use the data for additional summarization of migration events. This report addresses the Siting of Renewable Energy Projects: Wind energy concern of the Wisconsin Focus on Energy: Environmental Research Program. The recent workshop entitled: "Applying radar technology to migratory bird and bat conservation and management: strengthening and expanding a collaborative effort" held October 23-26, 2006, in Albuquerque, New Mexico, identified the need of resource managers for decision support tools with regard to wind energy development as a high priority for future work.

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Wildlife Society. 2007. Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat. Wildlife Society's Technical Review 07-2.

Development of wind power offers promise of contributing to renewable energy portfolios to reduce greenhouse gas emissions from carbon-based sources. This report summarizes information on the impacts of wind energy facilities on wildlife and wildlife habitat, including state and federal permitting processes, wildlife fatality, habitat loss and modification, animal displacement and fragmentation, offshore development, and issues surrounding monitoring and research methodology, including the use of technological tools.

Article Type: Proceedings (Book Chapters)

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Byrne, S. 1983. Bird Movements and Collision Mortality at a Large Horizonal Axis Wind Turbine. Cal-Neva Wildlife Transactions. Pg. 76.

Abstract: We have been studying bird movements and collision mortality as part of Pacific Gas and Electric Company's performance monitoring program for a 350 food boeing Mod-2 wind turbine. This machine is located on the western edge of the Suisun Marsh 4 miles south of Cordelia, Solano County, California.

Raptor and waterfowl movements were surveyed prior to construction. In the fall of 1982 we monitored nocturnal migration over the site for 6 weeks using a portable ceilometers-image intensifier system. Dead bird searches were conducted 5 days a week during this period and once weekly thereafter. Weather data were collected to determine the relationship between bird movement and nocturnal passerine migration over the wind turbine site. Raptor use of the area is moderate to high. Migration traffic rates are comparable to those in other parts of the western United States and lower than typical eastern migration rates. Collisions have occurred during all lighting and weather conditions, but collision mortality to date has been insignificant.

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Cooper, J.M. and S.M. Beauchesne. 2004. Does the Wind Power Industry Threaten Marbled Murrelets or Do Marbled Murrelets Threaten the Wind Power Industry? Pg. 1-14. *In:* T.D. Hooper, editor. Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. 1 March 2–6, 2004, Victoria, B.C. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, B.C.

Abstract: Green energy is being promoted by governments, industry, and environmentalists as a method of reducing greenhouse gas emissions and slowing global warming. Wind-based power is a rapidly growing area of green energy production throughout the world as improved turbine technology and green energy credits continue to lower costs of wind-based energy production. In Canada, wind farm projects exist in several provinces. No wind farms have been constructed in British Columbia, but dozens of projects are currently proposed. About 40 wind farms are projected to be built in British Columbia in the near future. Proposed and potential projects span the length of the coast, and could result in several thousand wind turbines being built on at-sea and inland sites.

The risk of bird mortality from collisions with wind turbines receives the most attention of all potential impacts associated with wind farms. Collision mortality is a cause of concern for the general public and government, even though most studies indicate that bird mortality rates are very low. In British Columbia, the threatened marbled murrelet (*Brachyramphus marmoratus*) is the highest profile bird species with a potential to be impacted by coastal wind farms. Due to the behavior, timing, location, and frequency of its flight patterns, the marbled murrelet could be at risk of colliding with wind turbines if they are located within the species' flight paths.

Developing sources of green energy and conserving marbled murrelet populations are both priorities for Environment Canada. Almost all farms proposed for coastal British Columbia seem to have potential to kill marbled murrelets. Can the wind power industry proceed to develop the wind-based energy potential of coastal British Columbia and avoid conflicts with marbled murrelet conservation, or will conservation concerns for marbled murrelets slow or stop development of the wind power industry? Both sides of this issue are discussed, and general mitigation measures are suggested.

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Johnson, G.D., M.D. Strickland, W.P. Erickson, and D.P. Young Jr. 2007. Use of data to develop mitigation measures for wind power development impacts to birds. pp. 241-257. *In:* de Lucas, M., G.F.E. Janss, et al. (Eds.) Birds and wind farms: risk assessment and mitigation. Quercus, Madrid, Spain.

No abstract available on line.

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Kuvlesky, 2007. Effects of Wind Farms on Birds. Nature and Environment Series No. 139. Council of Europe Publishing, Strasbourg.

No abstract available on line.

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Strickland, D. 2004. Overview of Non-Collision Related Impacts from Wind Projects. WIND ENERGY & BIRDS/BATS WORKSHOP PROCEEDINGS. Washington, DC. http://eagleharbortwp.org/pdf/wind/WEBBProceedings09142004Final.pdf#page=42

Abstract: There are a variety of direct and indirect, long-term and short-term non-collision impacts that wind projects may have on birds. Direct loss of habitat results from the construction of turbine pads, roads, and substations. Indirect loss of habitat may occur from birds' behavioral responses to development, such as avoiding wind plant facilities and areas surrounding them. Long-term habitat impacts result from the construction of relatively permanent structures that remove habitat for the life of a project and from birds avoiding habitat disturbed by a wind plant and not habituating (i.e., becoming accustomed) to wind plant features. Short-term habitat impacts occur while habitat disturbed temporarily during construction of the wind plant is being restored and/or while birds habituate to the disturbance.

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Strickland, D. 2004. Non-Fatality and Habitat Impacts on Birds from Wind Energy Development. Wind Energy & Birds/Bats Workshop Proceedings. http://eagleharbortwp.org/pdf/wind/WEBBProceedings09142004Final.pdf#page=42.

This session focused on discussion of non-collision impacts of wind energy projects on birds, primarily impacts to habitat. The presentation included information about the impacts of habitat fragmentation, disturbance, and site avoidance from wind turbines, as well as from roads, transmission facilities, and other related construction at wind project sites. Whether birds habituate to the presence of turbines and the influence of regional factors were also addressed.

Sub-category: Avian – Upland Gamebirds - Galliformes

Topic: Indirect Effects

Article Type: Peer-reviewed

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Andren, H., P. Angelstam, E. Lindstrom and P. Widen. 1985. Differences in predation pressure in relation to habitat fragmentation: an experiment. Oikos 45: 273-277.

Abstract: In the holarctic zone many medium-sized herbivores exhibit cyclic fluctuations, which generally disappear towards the south. In Fennoscandia, cycles in abundance of tetraonid birds are found within the boreal zone but not south of it. The hypothesis that disappearance of cycles towards the south is due to increased predation pressure, predicts a gradient in predation pressure in Sweden across the border between the boreal zone and the boreo-nemoral zone. This was tested using dummy nests to measure predation pressure. As predicted, we found higher predation rate south of the border and lower predation rate north of it. The rate of predation on experimental dummy nests was correlated with the abundance of corvid birds, which in turn was positively related to the proportion of agricultural land, human density and to the degree of fragmentation of forests.

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Andren, H. and P. Angelstam. 1988. Elevated predation rates as an edge effect on habitat islands: experimental evidence. Ecology 69(2):544-547.

Abstract: Studies of the fauna and flora of habitat islands in a fragmented landscape have usually applied island biogeographic theory to explain patterns of distribution and abundance of organisms on the habitat islands. However, as pointed out by MacArthur and Wilson (1967:114), habitat islands are very different from true islands. A habitat island is not surrounded by a habitat which is as hostile to organisms as the sea is to most terrestrial organisms. The surroundings of a habitat island contain both potential competitors and predators that may enter and interact with species living inside the island. The effect of such interactions from adjacent habitats, a type of edge effect, should increase as the size of the habitat island decreases, because the ratio of circumference to area increases as islands become smaller (Levenson 198 1). The loss of bird species from forest fragments as fragmentation progresses is well documented (Svensson 1978, Whitcomb et al. 1981, Ambuel and Temple 1983, Helle 1984), but in most cases the cause of extinction is unknown. A number of explanations have been suggested for this decline in the number of species (see, for example, Whitcomb et al. 1981). Some of these explanations take into account interspecific interactions from outside the habitat islands, e.g., increased brood parasitism (Brittingham and Temple 1983) and increased nest predation (Robbins 1980, Ambuel and Temple 1983) in small forest fragments as compared to large ones. Wilcove (1985) tested the idea that the difference in nest predation rates within small vs. large forest fragments is one mechanism causing reduction in the bird faunas of small fragments. He found a higher predation rate on dummy nests in small as compared to large forest fragments. Furthermore, Wilcove et al. (1986) found that predation rate was higher closer to the forest edge, suggesting that the high predation rate in small forest fragments was due to predators living in the surrounding habitat and penetrating the forest fragment. To see if this pattern might be a general feature of fragmented landscapes, we tested whether predation rate on ground nests in forest fragments is influenced by distance from farmland-forest edge. The study was performed in the same type of environment and in the same way as Wilcove (1985) and Wilcove et al. (1986). This replication of previous studies is important in determining the generality of results.

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Bui, T.D., J.M. Marzluff, and B. Bedrosian. 2010. Common Raven Activity in Relation to Land use in Western Wyoming: Implications for Greater Sage-Grouse Reproductive Success. The Condor 112(1):65-78

Abstract: Anthropogenic changes in landscapes can favor generalist species adapted to human settlement, such as the Common Raven (*Corvus corax*), by providing new resources. Increased densities of predators can then negatively affect prey, especially rare or sensitive species. Jackson Hole and the upper Green River valley in western Wyoming are experiencing accelerated rates of human development due to tourism and natural gas development, respectively. Increased raven populations in these areas may negatively influence the Greater Sage-Grouse (*Centrocercus urophasianus*), a sensitive sagebrush specialist. We investigated landscape-level patterns in raven behavior and distribution and the correlation of the raven data with the grouse's reproductive success in western Wyoming. In our study areas towns provide ravens with supplemental food, water, and nest sites, leading to locally increased density but with apparently limited (<3 km) movement by ravens from towns to adjacent areas of undeveloped sagebrush. Raven density and occupancy were greatest in land covers with frequent human activity. In sagebrush with little human activity, raven density near incubating and brooding sage-grouse was elevated slightly relative to that expected and observed in sagebrush not known to hold grouse. Raven occupancy near sage-grouse

nests and broods was more highly correlated with sage-grouse success than were raven density and behavior, suggesting that the majority of nest predation by ravens is most likely carried out by resident territorial individuals. Integrated region-wide improvement of sagebrush habitat, removal of anthropogenic subsidies, and perhaps removal or aversive conditioning of offending ravens might benefit sage-grouse populations in our study area.

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Hagen, C.A. Predation on Greater Sage-Grouse: Facts, Process, and Effects. Studies in Avian Biology (in press).

Abstract: Although Greater Sage-Grouse (*Centrocercus urophasianus*) face a suite of predators in sagebrush (*Artemisia* spp.) communities across the species' range, none of these predators specialize on sage-grouse. Greater Sage-Grouse are susceptible to predation from egg to adult leading to the hypothesis that predator control would be an effective conservation tool for sage-grouse populations. Therefore, I reviewed the literature pertaining to predator communities across the range of Greater Sage-Grouse and assessed the effects of predation on sage-grouse life history. I then provided a framework for evaluating when predator management may be warranted. Generally, nest success rates and adult survival are high, suggesting that on average predation is not limiting. However, in fragmented landscapes or in areas with subsidized predator populations predation may limit population growth. Few studies linked habitat quality to mortality rates, and fewer still linked these rates to predation. Predator management studies have not provided sufficient evidence to support implementation over broad geographic or temporal scales, but limited information suggests predator management may provide short-term relief for a population sink. Evaluating the need for predator management will require linking reduced demographic rates to habitat quality (fragmentation or degradation) or predator populations out of the natural range of variability (exotic species of subsidized populations). Alternatively, managers might consider predator management in translocation efforts to buffer recently released individuals from potentially elevated predation rates. Future work should quantify predator and alternate prey communities in habitats used by Greater Sage-Grouse.

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Pruett, C.L., M.A. Patten, and D.H. Wolfe. 2009. It's Not Easy Being Green: Wind Energy and a Declining Grassland Bird. BioScience 59(3):257–262.

Abstract: The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is an umbrella species for the short- and mixed-grass prairie ecosystem of the south-central United States. This species has suffered large population declines over the last century that mirror the loss of prairie. Populations have become increasingly fragmented, and habitat connections between populations are being severed. A possible new threat to lesser prairie-chickens is the rapid development of wind-energy facilities throughout their habitat. In addition to contributing to the loss of prairie, these facilities could serve as barriers to movement if birds avoid wind turbines and their associated power transmission lines. We summarize evidence for avoidance behavior in birds, propose connectivity areas between distributional cores, propose strategies for conservation of lesser prairie-chickens, and encourage lawmakers to adopt state and federal regulations on wind-farm placement. Without a concerted effort, lesser prairie-chickens and similar species are likely to disappear, as will the southern prairie on which they depend.

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Pruett, C.L., M.A. Patten, and D.H. Wolfe. 2009. Avoidance Behavior by Prairie Grouse: Implications for Development of Wind Energy. Conservation Biology 23(5):1253-1259.

Abstract: New wind-energy facilities and their associated power transmission lines and roads are being constructed at a rapid pace in the Great Plains of North America. Nevertheless, little is known about the possible negative effects these anthropogenic features might have on prairie birds, one of the most threatened groups in North America. We examined radiotelemetry tracking locations of Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) and Greater Prairie-Chickens (*T. cupido*) in two locations in Oklahoma to determine whether these birds avoided or changed movement behavior near power lines and paved highways. We tracked 463 Lesser Prairie-Chickens (15,071 tracking locations) and 216 Greater Prairie-Chickens (5,750 locations) for 7 and 3 years, respectively. Individuals of both species avoided power lines by at least 100 m and Lesser Prairie-Chickens avoided one of the two highways by 100 m. Prairie chickens crossed power lines less often than expected if birds moved randomly ($p < 0.05$) but did not appear to perceive highways as a movement barrier ($p > 0.05$). In addition, home ranges of Lesser Prairie-Chickens overlapped the power line less often than would be expected by chance placement of home ranges; this result was supported by kernel-density estimation of home ranges. It is likely that new power lines (and other tall structures such as wind turbines) will lead to avoidance of previously suitable habitat and will serve as barriers to movement. These two factors will likely increase fragmentation in an already fragmented landscape if wind energy development continues in prairie habitats.

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van den Berg, G.P. 2004. Effects of the wind profile at night on wind turbine sound. Journal of Sound and Vibration 277: 955-970.

Abstract: Since the start of the operation of a 30 MW, 17 turbine wind park, residents living 500 m and more from the park have reacted strongly to the noise; residents up to 1900 m distance expressed annoyance. To assess actual sound immission, long term measurements (a total of over 400 night hours in 4 months) have been performed at 400 and 1500 m from the park. In the original sound assessment a fixed relation between wind speed at the reference height (10 m) and the hub height (98 m) had been used. However, measurements show that speed of the wind turbines and consequentially up to 15 dB higher sound levels, relative to the same reference wind speed in daytime. Moreover, especially high rotational speeds the turbines produce a ‘thumping’, impulsive sound, increasing annoyance further. It is concluded that prediction of noise immission at night from (tall) wind turbines is underestimated when measurement data are used (implicitly) assuming a wind profile valid in daytime.

Article Type: Technical Report

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Becker, J.M., C.A. Duberstein, J.D. Tagestad, and J.L. Downs. 2009. Sage-Grouse and Wind Energy: Biology, Habits, and Potential Effects of Development. Prepared for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind & Hydropower Technologies Program under Contract DE-AC05-76RL01830. http://www.pnl.gov/main/publications/external/technical_reports/pnnl-18567.pdf

Summary: Proposed development of domestic energy resources, including wind energy, is expected to impact the sagebrush steppe ecosystem in the western United States. The greater sage-grouse relies on habitats within this ecosystem for survival, yet very little is known about how wind energy development may affect sage-grouse. The purpose of this report is to inform organizations of the impacts wind energy development could have on greater sage-grouse populations and identify information needed to fill gaps in knowledge.

Sage-grouse are highly dependent on sagebrush-dominated landscapes for all phases of their life history. Much of their current range overlaps with wind power resources characterized as superb to good across 11 western states. Sage grouse may utilize different habitats during different seasons and usually require a large home range. However, they are habitual, using specific locales during all seasons, and are sensitive to habitat disturbance. Sage-grouse populations have generally been in decline since the mid-1960s; the species is currently under review for listing as threatened or endangered by the U.S. Fish and Wildlife Service.

Very little is known about wind energy and sage-grouse, but oil- and gas-field developments within the range of the sage-grouse often have caused measureable effects to their populations. Activities and disturbance related to both energy development scenarios are believed to pose some similar threats to the grouse. Sage-grouse populations typically decline following oil and gas development, and birds have been displaced from habitat near infrastructure and locations with human. Notably, it has been shown that female grouse nesting in developed areas had lower annual survival rates. Chick mortality rates also were higher within sight of oil wells.

It is not known to what extent the development of wind energy resources will affect sage-grouse populations. Information on local and landscape-level impacts is needed. Before-after control-impact studies are needed to determine impacts to grouse, and information gained could be used within an adaptive management strategy. Research protocols and efforts should be developed collaboratively between industry, resource management, and the research community.

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Manville, A.M., II. 2004. Prairie grouse leks and wind turbines: U.S. Fish and Wildlife Service justification for a 5-mile buffer from leks; additional grassland songbird recommendations. Division of Migratory Bird Management, USFWS, Arlington, VA, peer-reviewed briefing paper. 17 pp.

Issue: The U.S. Fish and Wildlife Service (FWS, Service, or we) recommended "... avoiding placing wind turbines within 5 miles [8 km] of known leks (communal pair formation grounds) in known prairie grouse habitat" (see p. 4, item 7, Site Development Recommendations) in our *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines*, a notice of its availability published July 10, 2003 in the *Federal Register*. Some have questioned the validity of this recommendation, specifically the distance metric. While many grouse biologists consider 3 distinct groups of grouse in North America, including forest grouse (*e.g.*, Ruffed, Blue, and Spruce), prairie grouse (*e.g.*, Greater and Lesser Prairie-chickens and Sharp-tailed Grouse), and Sage-grouse (F. Hall 2004 personal communication [hereafter pers. comm.]), the Service's guidance included prairie and sage grouse within the same general "prairie grouse" category. This briefing paper provides justification for the Service's recommendation for a 5-mile buffer from occupied prairie grouse leks.

The Service reiterates that our wind siting guidelines are voluntary; we are not restricting installation of wind turbines or wind facilities within a 5-mile radius of active leks. Prior to any site selection, we recommend that the wind consultant/company/contractor assess the complete habitat requirements and habitat use and needs of whatever species of prairie and sage grouse is involved (*e.g.,* Greater and Lesser Prairie-chickens, and Gunnison and Greater Sage-grouse, and Columbia Sharp-tailed Grouse) at the site. All habitat requirements of prairie grouse should be considered, *i.e.*, habitats for courting and breeding (leks), nesting, brooding, resting, feeding, migrating, and wintering. Given continuing uncertainties about structural impacts on prairie grouse, especially the lack of data regarding impacts from wind facilities, and the clearly declining trends in prairie grouse populations (see below), we urge a precautionary approach by industry and recommend a 5-mile buffer where feasible. The public comment period on our voluntary guidance will continue to be open through July 10, 2005. We strongly encourage all interested parties to provide suggestions and recommendations on our voluntary guidance that will help improve its reliability and update its usability. Comments on the distance metric, especially those derived from ongoing scientific studies, will be important.

It also was recommended that we include a brief discussion on the declining populations of grassland and sage-steppe obligate songbirds and the need to protect their habitats. This briefing statement will review their habitat needs and will briefly discuss disturbance and habitat fragmentation.

Article Type: Proceedings

Brennan, L.A., R.M. Perez, S.J. Demaso, B.M. Ballard, and W.P. Kuvlesky, Jr. 2009. Potential Impacts of Wind Farm Energy Development on Upland Game Birds: Questions and Concerns. Pp. 179–183. Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics. http://ckwri.tamuk.edu/fileadmin/user_upload/docs/misc_PDF/Quail/Brennan_et_al__2009__Upland_Game_Birds_.pdf

Abstract: Ecologists and wildlife managers have been concerned about the negative impacts of wind energy developments or wind farms on migratory birds such as passerines and raptors, as well as bats. However, we present a series of arguments that culminate in a plea to also consider the potential direct and indirect impacts of wind farms on resident and migratory upland game birds. We pose these arguments from both ecological and economic perspectives because economic impacts derived from hunters are a major driver that provides incentives for landowners to sustain habitats, not only for upland game birds, but also for scores of other terrestrial wildlife species as well. The primary concern regarding the impacts of wind farms on upland game birds seems to revolve around the widespread fragmentation that results, not only from placement of the wind turbine towers, but also from the infrastructure of roads needed to construct and service them and the transmission lines required to access the continental electrical power grid. We consider these issues from the standpoint of habitat resources needed to sustain both resident (Northern Bobwhite, *Colinus virginianus*; Wild Turkey, *Meleagris gallopavo*; prairie-chickens, *Tympanuchus* spp.; and migratory Mourning Dove, *Zenaida macroura;* and White-winged Dove, *Z. asiatica*) game

birds. Implementation of policies and procedures, such as the 12-point position statement on wind energy development and wildlife as proposed by The Wildlife Society, is critically needed to conserve upland game birds and all wildlife populations during the course of planning and locating wind farms.

Subcategory: Infrastructure

Topic: Trade-off

Article Type: Peer-reviewed

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Cohn, J. P. 2008. How Ecofriendly Are Wind Farms? BioScience 58(7):576-578.

Paul Cryanwas surprised and curious. Cryan had been studying bats since 1990, but only in 2003 did he learn that bats were being killed at wind energy farms. Cryan wanted to know why the bats, whose visual and echolocation abilities allow them to find and catch flying insects at night and avoid obstacles in the dark, run into or otherwise are killed by rotating turbine blades. Why would bats be around wind turbines in the first place? And which species were most at risk? “It took all of us by surprise,” says Cryan, a research biologist at the US Geological Survey’s Fort Collins Science Center in Colorado. Cryan was speaking of the bat community’s reaction to news that hundreds of the flying mammals had died one night at Mountaineer Wind Energy Center in Thomas, West Virginia, and, later, at other wind farms throughout the United States, Canada, and Europe. “The researchers [at Mountaineer] were looking for birds, not bats. It was so strange. We had not seen bats killed before in substantial numbers at any human structures.” Not just bats but also birds are killed at wind farms, which have been touted as more environmentally friendly energy sources than coal, oil, and gas. After all, wind turbines produce no air, water, or thermal pollutants, and emit no greenhouse gases. “If we don’t do wind, we’ll wind up doing coal,” warns Robert Thresher, director of the National Wind Technology Center at the US Department of Energy’s National Renewable Energy Laboratory in Golden, Colorado. Wind farms may fragment the environment, however, and make it unusable for some birds.

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Kuvlesky, W.P., Jr., L.A. Brennan, M.L. Morrison, K.K. Boydston, B.M. Ballard, and F.C. Bryant. 2007. Wind Energy Development and Wildlife Conservation: Challenges and Opportunities. Journal of Wildlife Management 71:2487-2498.

Abstract: Wind energy development represents significant challenges and opportunities in contemporary wildlife management. Such challenges include the large size and extensive placement of turbines that may represent potential hazards to birds and bats. However, the associated infrastructure required to support an array of turbines—such as roads and transmission lines—represents an even larger potential threat to wildlife than the turbines themselves because such infrastructure can result in extensive habitat fragmentation and can provide avenues for invasion by exotic species. There are numerous conceptual research opportunities that pertain to issues such as identifying the best and worst placement of sites for turbines that will minimize impacts on birds and bats. Unfortunately, to date very little research of this type has appeared in the peer-reviewed scientific literature; much of it exists in the form of unpublished reports and other forms of gray literature. In this paper, we summarize what is known about the potential impacts of wind farms on wildlife and identify a 3-part hierarchical approach to use the scientific method to assess these impacts. The Lower Gulf Coast (LGC) of Texas, USA, is a region currently identified as having a potentially negative impact on migratory birds and bats, with respect to wind farm development. This area is also a region of vast importance to wildlife from the standpoint of native diversity, nature tourism, and opportunities for recreational hunting. We thus use some of the emergent issues related to wind farm development in the LGC—such as siting turbines on cropland sites as opposed to on native rangelands—to illustrate the kinds of challenges and opportunities that wildlife managers must face as we balance our demand for sustainable energy with the need to conserve and sustain bird migration routes and corridors, native vertebrates, and the habitats that support them.

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Langston, R.H.W. and J. D. Pullan. 2004. Effects of wind farms on birds. Nature and Environment No. 139. Council of Europe Publishing, Strausberg.

Executive Summary: This report was commissioned by the Council of Europe for the Bern Convention as an update of the one commissioned by them last year and presented to the 22nd meeting of the Standing Committee for information. It's remit is to:

Analyze the impact of windfarms on birds, establishing criteria for their environmental impact assessment and developing guidelines on precautions to be taken when selecting sites for windfarms.

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Sagrillo, M. 1995. Wind Generators and Birds: Power Politics? Home Power 46:30-34.

Abstract: Lately, a number of articles have been published in various periodicals bringing attention to a problem that is occurring on wind farms. It seems that dead birds have been found at a few locations. Some writers have even gone so far as to dub the wind generators "raptor-matics" and cuisinarts of the sky!"

Many Home Power readers considering a wind generator have asked about the seriousness of this problem. They are concerned that if they install a wind generator they will be responsible for batting birds all over the neighborhood. It's time to address this potentially serious issue. All of the studies done to date on bird mortalities associated with wind power have been done on wind farm-sized equipment. We'll take a look at this problem, what conclusions have been drawn, and speculate on why. From there, we'll apply this information to home sized systems.

Subcategory: Infrastructure

Topic: Trade-off

Article Type: Technical Report

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Hötker, H., K.-M. Thomsen, and H. Jeromin. 2006. Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats - facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation. Michael-Otto-Institut im NABU, Bergenhusen.

Summary: The purpose of this report is to compile and to evaluate the available information on the impacts of exploitation of renewable energy sources on birds and bats. The focus is on wind energy as there is only little information on the impact on birds and bats of other sources of renewable energy. The report aims at better understanding the size of the impact, the potential effects of re-powering (exchanging small old wind turbines by new big turbines), and possible measures to reduce the negative impact on birds by wind turbines. In addition the need for further research is highlighted. The evaluation is based on 127 separate studies (wind farms) in ten countries, most of them in Germany. Most studies were brief (not more than two years) and did not include the preconstruction period. Before-After Control Impact studies that combine data collection before and after, in this case construction of a wind farm, on both the proposed development site and at least one reference site were rare. In only a few cases, would the design of the study and the length of the study period theoretically allow statistically significant effects of wind farms on birds and bats to be found at all. Assessments of impacts, therefore, are usually based on few studies only. This report includes all studies readily available to the authors, irrespective of the length of the study period and the quality of the study design. In order to base the assessments on as many independent samples as possible even rather unsystematic observations were included. The information of the data was reduced to a level that justified the application of sign tests. The compilation of many different individual studies gave the following results: The main potential hazards to birds and bats from wind farms are disturbance leading to displacement or exclusion and collision mortality. Although there is a high degree of agreement among experts that wind farms may have negative impacts on bird populations no statistically significant evidence of negative impacts on populations of breeding birds could be found. There was a tendency waders nesting on open grounds to be displaced by wind farms. Some passerines obviously profited from wind farms. They were probably affected by secondary impacts, e.g. changes in land management or abandonment from agricultural use next to the wind plants. The impact of wind farms on non-breeding birds was stronger. Wind farms had significantly negative effects on

local populations of geese, Wigeons, Golden Plovers and Lapwings. With the exceptions of Lapwings, Black-tailed Godwits and Redshanks most bird species used the space close to wind turbines during the breeding season. The minimal distances observed between birds and pylons rarely exceeded 100 m during the breeding season. Some passerines showed a tendency to settle closer to bigger than to smaller wind turbines. During the non-breeding season many bird species of open landscapes avoided approaching wind parks closer than a few hundred metres. This particularly held true for geese and waders. In accordance with published information disturbance of geese may occur at least up to 500 m from wind turbines. For most species during the non-breeding season, the distances at which disturbance could be noted increased with the size of the wind turbines. For Lapwings this relationship was statistically significant. There was no evidence that birds generally became „habituated“ to wind farms in the years after their construction. The results of the few studies lasting longer than one season revealed about as many cases of birds occurring closer to wind farms (indications for the existence of habituation) over the years as those of birds occurring further away from wind farms (indications for the lack of habituation). The question whether wind farms act as barriers to movement of birds has so far received relatively little systematic scientific attention. Wind farms are thought to be barriers if birds approaching them change their flight direction, both on migration or during other regular flights. There is evidence for the occurrence of a barrier effect in 81 bird species. Geese, Common Cranes, waders and small passerines were affected in particular. However, the extent to which the disturbances due to wind farms of migrating or flying birds influences energy budgets or the timing of migration of birds remains unknown. Collision rates (annual number of killed individuals per turbine) have only rarely been studied with appropriate methods (e. g. with controls of scarvenger activities). In particular, such studies are missing for Germany. Collision rates varied between 0 and more than 50 collisions per turbine per year for both birds and bats. Obviously the habitat influenced the number of collisions. Birds were at high risks at wind farms close to wetlands where gulls were the most common victims and at wind farms on mountain ridges (USA, Spain), where many raptors were killed. Wind farms in or close to forests posed high collision risks for bats. For both birds and bats, the collision risk increased with increasing size of the wind turbine. The relationship, however, was not statistically significant. Gulls and raptors accounted for most of the victims. In Germany the relatively high numbers of White-tailed Eagles (13) and Red Kites (41) killed give cause for concern. Germany hosts about half of the world population of breeding Red Kites and has a particular responsibility for this species. Bird species that were easily disturbed by wind farms (geese, waders) were only rarely found among the victims. Bats were struck by wind turbines mostly in late summer or autumn during the period of migration and dispersal. Population models created by the software VORTEX revealed that significant decreases in size of bird and bat populations may be caused by relatively small (0,1 %) additive increases in annual mortality rates, provided they are not counter acted by density dependent increases in reproduction rates. Short-lived species with high reproductive rates are more affected than long-lived species with low reproductive rates. The latter, however, are less able to substitute additional mortality by increasing reproductive rates. The effects of „repowering“ (substitution of old, small turbines by new turbines with higher capacity) on birds and bats is assessed by the available data and by simple models. There is no information, however, on the effects of the newest generation of very large wind turbines. According to current knowledge, repowering will reduce negative impacts on birds and bats (disturbance and mortality) if the total capacity of a wind farm is not changed (many small turbines are replaced by few big turbines). In a scenario in which the capacity of a wind farm is increased 1.5 fold, negative impacts start to dominate. In case of a doubling of wind farm capacity, repowering increases the negative impacts of the wind farm. Repowering offers the chance to remove wind farms from sites that are associated with high impacts or risks for birds and bats. New turbines could be constructed on sites that are likely to be less problematic with respect to birds and bats. Effective methods of reducing the negative impacts of wind energy use on birds and bats include:

- choice of the right site for wind farms (avoidance of wetands, woodlands, important sites for sensitive non-breeding birds and mountain ridges with high numbers of raptors and vultures),
- measures to reduce the attractivness of wind farm sites for potential collision victims,
- configuration of turbines within wind farms (placement of turbines parallel to and not accross the main migration or flight directions of birds),
- construction of wind turbines: replacement of lattice towers, wire-cables and overhead power lines.

Measures to increase the visibility of wind turbines and to reduce the effects of illumination remain to be studied. In spite of many publications on windfarms and birds there still is a great demand for further research. First of all there is an urgent need for reliable data on collision rates at wind turbines of birds and bats in Germany. This holds true particularly for the new and big turbines which will replace the present generation of wind turbines. It is still unclear whether these big and necessarily illuminated turbines pose a high collision risk to nocturnal migrants which have not yet been greatly affected by smaller turbines. The high collision rates of Red Kites in Germany also merit urgently study. The aim of the research has to be a quick reduction of the collision rates. The sensitivity to wind farms of many other bird species that are of particular nature conservation interest (storks, raptors, Cranes) has not yet been sufficiently studied. There is hardly any information on the impacts of arrays of solar panels on birds and bats. Studies should be initiated as soon as possible.

Article Type: Thesis

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Jarvis, C.M. 2005. An Evaluation of the Wildlife Impacts of Offshore Wind Development Relative to Fossil Fuel Power Production. Master's Thesis, University of Delaware. 123 pp.

Abstract**:** Off the eastern coast of the United States lies a unique and untapped natural resource that has only recently been recognized: offshore wind energy. Hailed by many as a clean, virtually limitless source of renewable energy, offshore wind energy has great potential for reducing air pollution, lessening the United States' dependence on foreign oil supply, and mitigating the impacts of global climate change. The promises of offshore wind energy, however, are not without pitfalls. Potential adverse impacts on local and migrating wildlife species are frequently cited as an important issue of concern when considering the development and siting of an offshore wind facility. These concerns are not without merit: impacts to wildlife species may occur during all phases of offshore wind development, and include habitat alteration, habitat displacement, increased levels of underwater noise and vibration, and in some cases, mortality.

While public opposition to offshore wind development often focuses around concerns for wildlife species, current methods of energy production, such as fossil fuel power plants, impact wildlife species as well. These impacts include the annual entrainment and impingement of billions of aquatic organisms on a power plant's cooling water intake screens, thermal pollution resulting from the discharge of heated cooling water back into the water body from which it was withdrawn, habitat alteration from the extraction, processing, and transportation of coal or oil to a power plant, heavy metal contamination of aquatic environments from air emissions, and the acidification of aquatic and terrestrial habitats.

This thesis compares the wildlife impacts of offshore wind development to the wildlife impacts of fossil fuel power production. Such a comparison has, to date, been absent from the debate over offshore wind technology. This research attempts to better understand the wildlife impacts of offshore wind energy, and inform the debate over offshore wind power, by considering the wildlife impacts of the proposed Cape Wind facility (off Cape Cod, MA) in light of the wildlife impacts of the nearby Brayton Point power plant (Somerset, MA). These two facilities are geographically proximate and serve the same power pool. Data were obtained from existing literature, including grey literature, rather than from field measurements. Quantitative comparisons were adjusted for differences in electrical output between the two power plants.

This research concludes that from a quantitative perspective, Brayton Point has a larger impact on wildlife species than Cape Wind. The former includes hundreds of birds killed by oil spills, thousands of acres of land disturbed, and billions of fish, fish larvae, and fish eggs killed annually by entrainment, impingement, and thermal discharge. The effects of acid precipitation and heavy metal contamination are also known to have long-lasting impacts on wildlife species, including habitat exclusion, physical impairment, and reduced breeding potential. While offshore wind facilities are not without their own set of adverse impacts on wildlife species, these impacts must not be viewed in isolation. It is only when the wildlife impacts of offshore wind development are compared relative to those from fossil fuel power production can they be truly understood.

Major Category – General Energy Development

Sub-category: Avian (Passerine)

Topics: Indirect Effects - Habitat Use/Environmental

Article Type: Peer-reviewed

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Ingelfinger, F. and S. Anderson. 2004. Passerine Response to Roads Associated with Natural Gas Extraction in a Sagebrush Steppe Habitat. Western North American Naturalist 64(3): 385–395

ABSTRACT.—Natural gas extraction and field development are pervasive throughout the sagebrush steppe of Wyoming. We conducted this study to determine how roads associated with natural gas extraction affect the distribution of breeding songbirds in sagebrush steppe habitat. The study encompassed dirt and paved roads in the Jonah Field II and Pinedale Anticline Project Area in Sublette County, Wyoming. Sites are dominated by Wyoming big sagebrush (*Artemisia tridentata*), and common passerines include sagebrush obligates: Brewer's Sparrows (*Spizella breweri*), Sage Sparrows (*Amphispiza belli*), and Sage Thrashers (*Oreoscoptes montanus*); and non-obligates: Horned Larks (*Eremophila alpestris*) and Vesper Sparrows (*Pooecetes gramineus*). Species relative density was measured using 50-m-radius point counts during spring 1999 and 2000. Four roads with low traffic volumes (700–10 vehicles per day) were surveyed and point counts were centered at variable distances from the road surface such that relative densities were measured 0–600 m from the road's edge. Density of sagebrush obligates, particularly Brewer's and Sage Sparrow, was reduced by 39%–60% within a 100-m buffer around dirt roads with low traffic volumes (700–10 vehicles per day). While a 39%–60% reduction in sagebrush obligates within 100 m of a single road may not be biologically significant, the density of roads created during natural gas development and extraction compounds the effect, and the area of impact can be substantial. Traffic volume alone may not sufficiently explain observed declines adjacent to roads, and sagebrush obligates may also be responding to edge effects, habitat fragmentation, and increases in other passerine species along road corridors. Therefore, declines may persist after traffic associated with extraction subsides and perhaps until roads are fully reclaimed.

Sub-category: Avian – sage-grouse

Topics: Indirect Effects - Habitat Use/Environmental

Article Type: Peer-reviewed

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Connelly, J.W., M.A. Schroeder, A.R. Sands and C.E. Braun. 2000. Guidelines to Manage Sage Grouse Populations and Their Habitats. Wildlife Society Bulletin 28(4):967-985.

Abstract: The status of sage grouse populations has been a concern to sportsmen and biologist for >80 years. Despite management and research efforts that date to the 1930s, breeding populations of this species have declined throughout much of its range. In May 1999, the western sage grouse (*C. urophasianus phaios*) in Washington was petitioned for listing under the Endangered Species Act because of population and habitat declines (C. Warren, United States Fish and Wildlife Service, personal communication). Sage grouse populations are allied closely with sagebrush (Artemisia spp.). Despite the well-known importance of this habitat to sage grouse and other sagebrush obligates, the quality and quantity of sagebrush habitats have declined for at least the last 50 years. Braun et al. (1977) provided guidelines for maintenance of sage grouse habitats. Since publication of those guidelines, much more information has been obtained on sage grouse. Because of continued concern about sage grouse and their habitats and a significant amount of new information, the Western States Sage and Columbian Sharp-tailed Grouse Technical Committee, under the direction of the Western Association of Fish and Wildlife Agencies, requested a revision and expansion of the guidelines originally published by Braun et al. (1977). This paper summarizes the current knowledge of the ecology of sage grouse and, based on this information, provides guidelines to manage sage grouse populations and their habitats.

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Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation Assessment of Greater Sage-grouse and Sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished report. Cheyenne, Wyoming.

Executive Summary (pg ES-3): Energy development for oil and gas influences sagebrush habitats by physical removal of habitat to construct well pads, roads, and pipelines. Indirect effects include habitat fragmentation and soil disturbance along roads, spread of exotic plants, and increased predation from raptors that have access to new perches for nesting and hunting. Noise disturbance from construction activities and vehicles also can disrupt sage-grouse breeding and nesting. Development of oil and gas resources will continue to be a significant influence on sagebrush habitats and sage-grouse because of advanced technological capability to access and develop reserves, high-demand for oil and gas resources, and the large number of applications submitted (4,279 in fiscal year 2002) and approved each year.

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Doherty, K.E., D.E. Naugle, B.L. Walker, J.M. Graham. 2008. Greater Sage-Grouse Winter Habitat Selection and Energy Development. Journal of Wildlife Management 72:187-195.

Abstract: Recent energy development has resulted in rapid and large-scale changes to western shrub-steppe ecosystems without a complete understanding of its potential impacts on wildlife populations. We modeled winter habitat use by female greater sage-grouse (*Centrocercus urophasianus*) in the Powder River Basin (PRB) of Wyoming and Montana, USA, to 1) identify landscape features that influenced sage-grouse habitat selection, 2) assess the scale at which selection occurred, 3) spatially depict winter habitat quality in a Geographic Information System, and 4) assess the effect of coal-bed natural gas (CBNG) development on winter habitat selection. We developed a model of winter habitat selection based on 435 aerial relocations of 200 radiomarked female sage-grouse obtained during the winters of 2005 and 2006. Percent sagebrush (*Artemisia* spp.) cover on the landscape was an important predictor of use by sage-grouse in winter. The strength of habitat selection between sage-grouse and sagebrush was strongest at a 4-km2 scale. Sage-grouse avoided coniferous habitats at a 0.65-km2 scale and riparian areas at a 4-km2 scale. A roughness index showed that sage-grouse selected gentle topography in winter. After controlling for vegetation and topography, the addition of a variable that quantified the density of CBNG wells within 4 km2 improved model fit by 6.66 Akaike's Information Criterion points (Akaike wt = 0.965). The odds ratio for each additional well in a 4-km2 area (0.877; 95% CI = 0.834–0.923) indicated that sage-grouse avoid CBNG development in otherwise suitable winter habitat. Sage-grouse were 1.3 times more likely to occupy sagebrush habitats that lacked CBNG wells within a 4-km2 area, compared to those that had the maximum density of 12.3 wells per 4 km2 allowed on federal lands. We validated the model with 74 locations from 74 radiomarked individuals obtained during the winters of 2004 and 2007. This winter habitat model based on vegetation, topography, and CBNG avoidance was highly predictive (validation R2 = 0.984). Our spatially explicit model can be used to identify areas that provide the best remaining habitat for wintering sage-grouse in the PRB to mitigate impacts of energy development.

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Holloran, M.J., R.C. Kaiser, W.A. Hubert. 2010. Yearling Greater Sage-Grouse Response to Energy Development in Wyoming. Journal of Wildlife Management 74: 65-72.

Abstract: Sagebrush (*Artemisia* spp.)-dominated habitats in the western United States have experienced extensive, rapid changes due to development of natural-gas fields, resulting in localized declines of greater sage-grouse (*Centrocercus urophasianus*) populations. It is unclear whether population declines in natural-gas fields are caused by avoidance or demographic impacts, or the age classes that are most affected. Land and wildlife management agencies need information on how energy developments affect sage-grouse populations to ensure informed land-use decisions are made, effective mitigation measures are identified, and appropriate monitoring programs are implemented (Sawyer et al. 2006). We used information from radio-equipped greater sage-grouse and lek counts to investigate natural-gas development influences on 1) the distribution of, and 2) the probability of recruiting yearling males and females into breeding populations in the Upper Green River Basin of southwestern Wyoming, USA. Yearling males avoided leks near the infrastructure of natural-gas fields when establishing breeding territories; yearling females avoided nesting within 950 m of the infrastructure of natural-gas fields. Additionally, both yearling males and yearling females reared in areas where infrastructure was present had lower annual survival, and yearling males established breeding territories less often, compared to yearlings reared in areas with no infrastructure. Our results supply mechanisms for population-level declines of sage-grouse documented in natural-gas fields, and suggest to land managers that current stipulations on development may not provide management solutions.

Managing landscapes so that suitably sized and located regions remain undeveloped may be an effective strategy to sustain greater sage-grouse populations affected by energy developments.

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Lyon, A.G. and S.H. Anderson. 2003. Potential Gas Development Impacts on Sage Grouse Nest Initiation and Movement. Wildlife Society Bulletin 31:486-491.

Abstract: The decline of greater sage grouse (*Centrocercus urophasianus*) over the last 50 years has raised concern over how natural gas development might affect sage grouse populations. We examined the effects of vehicular activity due to gas-well development near Pinedale, Wyoming, on productivity and movements of sage grouse. In 1998-1999, we captured and radiomarked 48 female sage grouse on 6 leks classified as disturbed or undisturbed, based on the presence or absence of natural gas development within 3 km. The mean distance from disturbed leks to selected nest sites was greater (P=0.019 with outliers removed, P= 0.004 with outliers included) than distance moved from undisturbed leks. Nest-initiation rate for hens from disturbed leks was 65%, while hens from undisturbed leks initiated nests 89% (P=0.07) of the time. Nest success at both disturbed and undisturbed leks was 50%. Our results suggest that light traffic disturbance (1-12 vehicles/day) during the breeding sea-son might reduce nest-initiation rates and increase distances moved from leks during nest-site selection. We recommend further investigation concentrating on hen behavior (i.e., distance moved from lek to nest site, breeding behavior, lek attendance), reproductive effort, and nest success in relation to natural gas development as development intensifies.

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Vander Haegen, W.M., M.A. Schroeder, and R.M. DeGraaf. 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. The Condor 104:496-506.

Abstract: Clearing of shrubsteppe communities for agriculture has created a highly fragmented landscape in eastern Washington, a condition that has been shown to adversely affect nesting success of birds in some forest and grassland communities. We used artificial nests monitored by cameras to examine relative effects of fragmentation, distance to edge, and vegetation cover on nest predation rates and to identify predators of shrubsteppe-nesting passerines and grouse. Predation rate for artificial nests was 26% (n = 118). Fragmentation had a strong influence on predation rates for artificial nests, with nests in fragmented landscapes about 9 times more likely to be depredated as those in continuous landscapes. Daily survival rate (+/- SE) for 207 real nests of 4 passerine species was also greater in continuous (0.978 +/- 0.004) than in fragmented (0.962 +/- 0.006) landscapes, although pattern of predation between real and artificial nests was not consistent among sites. Artificial nests were depredated by Common Ravens (*Corvus corax*), Black-billed Magpies (*Pica hudsonia*), Sage Thrashers (*Oreoscoptes montanus*), least chipmunks (*Tamias minimus*), and mice. Most nests in fragments were depredated by corvids (58%), whereas only Sage Thrashers and small mammals depredated nests in continuous landscapes. Increased predation by corvids and lower nest success in fragmented landscapes may have played a part in recent declines of some shrubsteepe birds. Future research should measure annual reproductive success of individual females and survival rates of juveniles and adults.

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Walker, B.L., D.E. Naugle, K.E. Doherty. 2007. Greater Sage-Grouse Population Response to Energy Development and Habitat Loss. Journal of Wildlife Management 71:2644-2654.

Abstract: Modification of landscapes due to energy development may alter both habitat use and vital rates of sensitive wildlife species. Greater sage-grouse (*Centrocercus urophasianus*) in the Powder River Basin (PRB) of Wyoming and Montana, USA, have experienced rapid, widespread changes to their habitat due to recent coal-bed natural gas (CBNG) development. We analyzed lek-count, habitat, and infrastructure data to assess how CBNG development and other landscape features influenced trends in the numbers of male sage-grouse observed and persistence of leks in the PRB. From 2001 to 2005, the number of males observed on leks in CBNG fields declined more rapidly than leks outside of CBNG. Of leks active in 1997 or later, only 38% of 26 leks in CBNG fields remained active by 2004–2005, compared to 84% of 250 leks outside CBNG fields. By 2005, leks in CBNG fields had 46% fewer males per active lek than leks outside of CBNG. Persistence of 110 leks was positively influenced by the proportion of sagebrush habitat within 6.4 km of the lek. After controlling for habitat, we found support for negative effects of CBNG development within 0.8 km and 3.2 km of the lek and for a time lag between CBNG development and lek disappearance. Current lease stipulations that prohibit development within 0.4 km of sage-grouse leks on federal lands are inadequate to ensure lek persistence and may result in impacts to breeding populations over larger areas. Seasonal restrictions on drilling and construction do not address impacts caused by loss of sagebrush and incursion of infrastructure that can affect populations over long periods of time. Regulatory agencies may need to increase spatial restrictions on development, industry may need to rapidly implement more effective mitigation measures, or both, to reduce impacts of CBNG development on sage-grouse populations in the PRB.

Article Type: Thesis

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Doherty, K.E. 2008. Sage-Grouse and Energy Development: Integrating Science with Conservation Planning to Reduce Impacts. Dissertation, The University of Montana, Missoula, MT.

Effective conservation planning in the face of rapid land use change requires knowledge of which habitats are selected at landscape scales, where those habitats are located, and how species ultimately respond to anthropogenic disturbance. I assessed sage-grouse (*Centrocercus urophasianus*) large scale habitat ecology and response to energy development in the winter and nesting seasons using radio-marked individuals in the Powder River Basin, Montana and Wyoming, USA. Landscape scale percent sagebrush (*Artemisia spp.*) cover at 4-km2 was the strongest predictor of use by sage-grouse in winter. After controlling for vegetation and topography, the addition the density of coal-bed natural gas wells within 4 km2 improved model fit (AIC -6.66, *wi* = 0.965) and indicated that sage-grouse avoided energy development. Nesting analyses showed that landscape context must be considered in addition to local scale habitat features (*wi* = 0.96). Findings provide managers a hierarchical filter in which to manage breeding habitats. Twice the amount of nesting habitat at 3, 5 and 10-km scales surrounded active leks versus random locations. Spatially explicit nesting and wintering models predicted independent sage-grouse locations (validation R2 ≥ 0.98). I incorporated knowledge of energy impacts into a study design that tested for threshold responses at regional scales analyzing 1,344 leks in Wyoming from 1997-2007. Potential impacts were indiscernible at 1-12 wells within 32.2 km2 of a lek (~1 well / 640 ac). At higher wells densities a time-lag showed higher rates of lek inactivity and steeper declines in bird abundance 4 years after than immediately following development. I spatially prioritized core areas for breeding sage-grouse across Wyoming, Montana, Colorado, Utah and the Dakotas and assessed risk of future energy development. Findings showed that bird abundance varies by state, core areas contain a disproportionately large segment of the breeding population and that risk of development within core areas varies regionally. My analyses document behavioral and demographic responses to energy development, offer new insights into large scale ecology of greater sage-grouse and provide resource managers with practical tools to guide conservation.

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Holloran, M.J. 2005. Greater Sage-Grouse (*Centrocercus Urophasianus*) Population Response to Natural Gas Field Development in Western Wyoming. Dissertation, University of Wyoming, Laramie.

Abstract: Sage-grouse (*Centrocercus* spp.) populations have declined dramatically throughout the western United States since the 1960s. Increased gas and oil development during this time has potentially contributed to the declines. I investigated impacts of development of natural gas fields on greater sagegrouse (*C. urophasianus*) breeding behavior, seasonal habitat selection, and population growth in the upper Green River Basin of western Wyoming. Greater sage-grouse in western Wyoming appeared to be excluded from attending leks situated within or near the development boundaries of natural gas fields. Declines in the number of displaying males were positively correlated with decreased distance from leks to gas-field-related sources of disturbance, increased levels of development surrounding leks, increased traffic volumes within 3 km of leks, and increased potential for greater noise intensity at leks. Displacement of adult males and low recruitment of juvenile males contributed to declines in the number of breeding males on impacted leks. Additionally, responses of predatory species to development of gas fields could be responsible for decreased male survival on leks situated near the edges of developing fields and could extend the range-of-influence of gas fields. Generally, nesting females avoided areas with high densities of producing wells, and brooding females avoided producing wells. However, the relationship between selected nesting sites and proximity to gas field infrastructure shifted between 2000 – 2003 and 2004, with females selecting nesting habitat farther from active drilling rigs and producing wells in 2004. This suggests that the long-term response of nesting populations is avoidance of natural gas development. Most of the variability in population growth between populations that were impacted and non-impacted by natural gas development was explained by lower annual survival buffered to some extent by higher productivity in impacted populations. Seasonal survival differences between impacted and non-impacted individuals indicates that a lag period occurs between when an individual is impacted by an anthropogenic disturbance and when survival probabilities are influenced, suggesting negative fitness consequences for females subjected to natural gas development during the breeding or nesting periods. I suggest that currently imposed development stipulations are inadequate to protect greater sage-grouse, and that stipulations need to be modified to maintain populations within natural gas fields.

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Kaiser, R.C. 2006. Recruitment by greater sage-grouse in association with natural gas development in western Wyoming. Thesis, University of Wyoming, Laramie, WY. 91 pp.

Abstract not available on internet

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Lyon, A.G. 2000. The potential effects of natural gas development on sage grouse (*Centrocercus urophasianus*) near Pinedale, Wyoming. Master's Thesis, University of Wyoming, Laramie. 121 p.

Abstract: Sage grouse (*Centrocercus urophasianus*) populations have been declining over the last half of the century due to such factors as habitat degradation and loss. As natural gas development has increased in Wyoming, so has the concern over how this type of development might effect sage grouse populations. Therefore a study was initiated on the Pinedale Mesa to examine the effects of natural gas and oil development on use, productivity, general movements and habitat use of sage grouse. A total of 80 grouse (60 adult and 20 chicks) were captured and radio-collared on six leks on the Pinedale Mesa between March-August 1998. Lek classification was determined by the presence of natural gas development within a 3 km buffer and topographic features surrounding the leks. The grouse were monitored and located (using radio telemetry techniques) on a weekly basis to determine lek use, nest site, early brood rearing, late brood rearing, summer and winter habitat selection. Vegetative data collected at use and random sites included: sagebrush density, canopy cover and height, grass and residual grass height and cover and forb cover. Results from the study indicated that hens captured on disturbed leks demonstrated lower nest initiation rates, traveled twice as far to next sites, and selected higher total shrub canopy cover and live sagebrush canopy cover than hens captured off of undisturbed leks. Also, most grouse chicks were lost during extreme early brood rearing from hens that mated on all leks. Therefore extreme early brood survival appears to be the limiting factor in sage grouse population stability on the Pinedale Mesa. Finally, four roosters, and five hens moved up to 60 miles to breed and next after capture on the Mesa. Consequently we hypothesize that the Mesa is critical winter range for multiple populations of sage grouse spanning a large demographic area.

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Smith, L.S. 2009. Greater Sage-Grouse and Energy Development in Northeastern Utah: Implications for Management. Master's Thesis, Utah State University, Logan. 104 pages.

Abstract: Concern regarding the effect of energy development on greater sage-grouse (*Centrocercus urophasianus*) is increasing as the search for fossil fuel intensifies. Sage-grouse may be especially sensitive to energy development because they require large, diverse areas of sagebrush (*Artemisia* spp.) habitat to complete their life cycle. Additionally, the network of pipelines, roads, and wells required by energy development may fragment sagebrush habitat isolating populations and contributing to genetic drift, inbreeding, local extinction, or rapid divergence. Seep Ridge, located in northeastern Utah, is one area where sage-grouse habitat and energy development plans overlap. Approved leases call for the construction of an additional 4,000 natural gas wells in an area currently occupied by a small sage-grouse population. This research was completed to 1) collect baseline data on the survival, reproductive success and habitat use of the Seep Ridge sage-grouse population, 2) examine sage-grouse habitat use patterns in relation to development, and 3) describe sage-grouse mitochondrial genetic diversity in 3 northeastern Utah populations relative to other parts of the species range.

I captured and monitored 16 sage-grouse from the Seep Ridge population in 2007 and 2008. Adult mortality rate of the Seep Ridge population was high (65.2%) and recruitment was low (7.1%) compared to other sage-grouse

populations in Utah. Additionally, the monitored sage-grouse used habitats located farther from wells more frequently than habitat located near wells, relative to well spacing. Current habitats occupied by this population do not meet recommended guidelines.

No unusual haplotype compositions were observed in the genetic survey of the northeastern Utah sage-grouse populations. However, differences in haplotype composition between the Anthro Mountain and Strawberry Valley populations and other northeastern grouse populations indicate there may be a barrier to gene flow in the area. I also documented that the Seep Ridge population is connected to another population inhabiting Ute Tribal land. This observation suggests that the populations inhabiting Ute Tribal land may constitute a source population to recolonize Seep Ridge during the post-energy development periods.

I recommend that mitigation measures incorporate restricting development in breeding habitat, maintaining connections between populations, and actions to reduce adult mortality on the summer range. I also recommend that biologists continue collecting genetic samples from northeastern Utah sage-grouse populations to understand population structure, divergent evolution, and inform decisions concerning translocation.

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Walker, B.L. 2008. Greater Sage-grouse Response to Coal-bed Natural Gas Development and West Nile virus in the Powder River Basin, Montana and Wyoming, USA. Ph.D. Dissertation, University of Montana, Missoula. 218 p.

Abstract: Understanding how population dynamics respond to landscape-scale disturbance and disease are crucial for effective wildlife management and conservation. Two new potential stressors on greater sage-grouse grouse (*Centrocercus urophasianus*) populations in the Powder River Basin of Montana and Wyoming are coal-bed natural gas (CBNG) development and West Nile virus (WNv). I first examined how CBNG development, habitat, and other landscape features influenced trends in the abundance of displaying males and the status of sage-grouse leks. Second, I used rates of WNv-induced mortality and seroprevalence from radio-marked birds to estimate rates of WNv infection. Third, I studies the influence of female characteristics, season, and environmental variables on nest, brood, and female survival. I then used population models to estimate potential impacts of WNv on population growth. From 2001-2005, numbers of males on leks in CBNG fields declined more rapidly than leks outside CBNG. Of leks active in 1997 or later, only 38% within CBNG remained active by 2004-2005, compared to 84% of leks outside CBNG. By 2005, leks in CBNG had 46% few males per active lek than leks outside CBNG. Persistence of 110 leks was positively influenced by proportion sagebrush habitat with 6.4 km of the lek and negatively affected by CBNG development at multiple scales. Prohibiting CBNG development within 0.4 km of sage-grouse leks is inadequate to ensure lek persistence. From 2003-2005, minimum WNv-related mortality rates from 1 July -15 September ranged from 2.4-13.3% and maximum possible rates ranged from 8.2-28.9%. In spring 2005 and 2006, 10.3% and 1.8% respectively, of newly-captured females tested seropositive for neutralizing antibodies to WNv. Annual WNv infection rates were lower in habitats without CBNG development. Summer mortality from WNv occurred every year, decreased annual female survival rates by 0-27% per year, and reduced estimates of population growth by 7-10% per year. Changes in epizootiology of WNv and in distribution and management of surface water from CBNG development will play an important role in long-term impacts of WNv on greater sage-grouse populations in the Powder River Basin. Management should focus on eliminating man-made water sources that support breeding mosquitos known to vector the virus.

Article Type: Technical Report

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Johnson, G.D., D.P. Young, Jr., W.P. Erickson, C.E. Derby, M.D. Strickland, and R.E. Good. 2000. Wildlife Monitoring Studies. Seawest Wind Power Project, Carbon County, Wyoming, 1995-1999. Final Report prepared for SeaWest Energy Corporation and Bureau of Land Management.

Executive Summary (pg iv): Aerial and ground sage grouse lek surveys were initiated to monitor trends in sage grouse use and distribution within each study area before, during and after construction of wind turbines. Habitat use and distribution of sage grouse in close proximity to turbine development areas were estimated by recording sage grouse pellets within big game pellet plots. Twenty-two known historic lek sites were visited during the aerial survey and ground visits. The maximum number of males counted on six leks monitored during all four study years on SR increased from 116 in 1995 to 166 in 1999. Mean sage grouse pellet density on the FCR study area during the winter period ranged from 0/ha in 1997/98 to 69/ha during the 1994/95 winter period. During the summer period, sage grouse pellet density on FCR was 11/ha in 1995 and 4/ha in 1997. On the SR study area, mean sage grouse pellet density during winter ranged from 85/ha in 1997/98 to 131/ha during the 1994/95 winter period. During the summer period, pellet density was 143/ha in 1995 and 32/ha in 1997.

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Naugle, D.E., K.E. Doherty, and B.L. Walker. 2006. Sage-Grouse Winter Habitat Selection and Energy Development in the Powder River Basin: Completion Report.

Executive Summary: The recent surge in coal-bed natural gas (CBNG) development has resulted in rapid and large-scale changes to sagebrush habitats in the Powder River Basin (PRB) of Montana and Wyoming without a complete understanding of its potential impacts to wildlife populations. As part of a larger study investigating the impacts of CBNG on greater sage-grouse (*Centrocercus urophasianus*), we conducted research on winter habitat use in the PRB to 1) identify landscape features that influence sage-grouse habitat selection, 2) to assess appropriate scale(s) at which selection occurs, and 3) to develop a conservation planning tool by spatially depicting winter habitat quality in a GIS. Vegetation and topographic variables drove the model which predicted an independent data set of winter sage-grouse locations (R2 = 0.961). After controlling for habitat quality, the addition of a variable quantifying the average number of wells/km2 within 1000 m of used and available points indicated that sage-grouse avoid CBNG development in otherwise suitable habitat. An Akaike weight of 0.998 showed that the model with habitat and energy development variables included has complete support as the best model to explain the information in the data set. Knowledge that sage-grouse avoid energy development in breeding (Naugle et al. 2006) and wintering seasons (this report) shows that conservation strategies to date to protect the species have been largely ineffective. An effective conservation strategy is one that limits the cumulative impact of disturbances across a landscape at all times of the year. There is still time to develop and 2 implement an effective conservation strategy in the PRB because some areas of high quality winter habitat are still undeveloped. Winter habitat is limited for birds along the border of Montana and Wyoming. Movements of radio-marked birds indicate that this non-migratory population remains in small parcels of suitable habitat to breed, raise broods, and spend the winter. The most suitable winter habitat in Montana and northern Wyoming encompasses only 13% of total land area and has already been impacted by surface mining activities. Expansion of CBNG development threatens to extirpate birds from otherwise suitable habitats and further isolate remaining populations. Risk of complete loss of this population is high if plans proceed to develop the entire northern study area because their non-migratory status and behavioral avoidance of CBNG will leave these birds with no other options. Comparatively more undeveloped winter habitat exists further south in Wyoming (south and east of the town of Buffalo) than along the border of Montana and Wyoming. Large pieces of undeveloped habitat near Buffalo provide winter habitat for a migratory population that nest up to 28 km to the north where winter habitat is poor. Some of these same good wintering areas also contain resident populations of nesting birds that distribute themselves around active leks with >20 males in attendance. Spatially-explicit planning tools, when coupled with knowledge of bird movements and active lek locations provide a biological basis for decision-makers to formulate an effective conservation strategy for sage-grouse. The next step for stakeholders is to formulate the strategy, evaluate alternatives and initiate implementation.

Sub-category: Mammals

Topics: Indirect Effects - Habitat Use/Environmental (Wildlife Damage Management)

Article Type: Proceedings

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Dudderar, G.R., S.R. Wintersteiny and W.H. Sangsteiz. 1997. Ecology and Control of Wildlife Damage to Electric Substations. Proc. East. Wildl. Damage Mgznt. Conf. 7;132-138.

Abstract: This study addresses several aspects of the ecology and control of wildlife damage to electric substations because the amount of existing research is not sufficient to make informed decisions about how best to minimize that damage. Records of 121incidents of animal-caused faults showed that 78°I° of the faults were caused by squirrels and raccoons and an average of 2,511customers lost service doting the outage caused by such a fault. Animal damage control measures were evaluated by observing challenges to cool measures by raccoons and squirrels at a substation. The control measures were breached twice because they had not been properly applied. In 1994, 301 transmission and distribution substations in Michigan were sampled and categorized based on various structural and habitat characteristics. Significant relationships ($p < 0.10$) were found between faulted substations and the number of nests in the substation, the distance of water from the substation, and the beam type used in the substation.