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WIND TURBINE INTERACTIONS WITH BIRDS AND BATS: A SUMMARY OF RESEARCH RESULTS AND REMAINING QUESTIONS

Fact Sheet: Second Edition

INTRODUCTION

The NWCC Wildlife Workgroup was formed in 1994, originally called the Avian Subcommittee, to provide a forum for dialogue among researchers, conservationists, wind industry representatives, and federal, state, and local officials to better understand bird and bat wind interaction issues. After conducting four national research meetings, producing a document guiding research (*Studying Wind Energy/ Bird Interactions: A Guidance Document*, 1999) and another paper (*Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States*, 2001), the workgroup recognized a need to summarize in a fact sheet what is known about bird and bat-wind interaction and what questions remain.

This fact sheet attempts to summarize in lay terms the results of research about wind and avian and bat interactions on land. The information presented here pertains only to land-based installations using wind turbines of 40 kW (kilowatts) or larger capacity. Some findings may need to be revisited as turbine heights increase. It does not address offshore development. This fact sheet is not intended as a conclusion on the subject; rather, it is a summary as of July, 2004. The Wildlife Workgroup intends to revise the fact sheet periodically as more is learned. Additional resources are available at www.nationalwind.org. Questions can also be directed to the NWCC staff at 1-888-764-WIND.

Wind energy has attracted attention in recent years as an increasingly economical means of generating electricity. In very simple terms, as the wind spins a turbine's rotor, a generator connected to the rotor generates electricity. Large wind turbines generate electricity at a lower cost than smaller ones, because an increase in rotor blade length means a larger increase in rotor swept area, and swept area is the key to productivity. Early turbines were mounted on towers 60 to 80 feet in height and had rotors 50 to 60 feet in diameter which turned at rates of 60 to 80 revolutions per minute (rpm). Today's wind machines are mounted on towers 200 to 260 feet in height and have rotors ranging from 150 to 260 feet in diameter that turn at rates of 11 to 28 rpm. Although some turbine models allow rotors to "overspeed" briefly to accommodate abrupt wind gusts, blade tip speeds under normal operating conditions have not increased appreciably with the use of larger turbines. The turbine's tip speed at rated output can range from 138-182 mph. The rotor speed range is 14.4-28.5 rpm.[1] Large turbines produce much more electricity per machine than small turbines, and there are generally fewer machines with wider spacing in modern wind developments. Still larger turbines are being developed for the future.

Wind turbines are typically described in terms of their "rated" (or "name-plate") power generating capacity, which can vary from a few hundred watts (W) to several megawatts (MW). 1 MW is equal to 1 million watts. A 1-MW turbine will

[1] These numbers are based on a chart of the 16 contemporary on land turbine models compiled by Sam Enfield, Atlantic Renewable Energy Corporation.

Wind Turbine Interactions With Birds and Bats: A Summary of Research Results and Remaining Questions is a consensus document of the NWCC.

typically generate between 2.5 million and 3.5 million kilowatt-hours (kWh) per year, depending upon the wind speeds at the site where it is located. The average American household uses approximately 10,000 kWh per year. However, there are wide regional variations in electricity use, from 12,000 kWh per household in some parts of the South to 6,000 kWh per household in California. This means that a 1-MW turbine may generate as much electricity as is used by 200 to 600 households.

Wind energy's ability to generate electricity without many of the environmental impacts associated with other energy sources (air pollution, water pollution, mercury emissions, and greenhouse gas emissions associated with global climate change) can significantly benefit birds, bats, and many other plant and animal species. However, the direct and indirect local and cumulative impacts of wind plants on birds and bats continue to be an issue. The populations of many bird and bat species are experiencing long-term declines, due not only to the effects of energy use, but many other human activities.

WHAT CURRENT STUDIES HAVE SHOWN

A number of wind plants have been studied to determine the potential impacts of wind development on birds and bats. These studies have included a variety of wind plants ranging from long - established plants in California to recently constructed wind plants in other regions of the country. While most of the studies of newer wind plants have been conducted in the West, a few studies have been conducted in the upper Midwest and the East. Some impacts to birds and bats have been demonstrated, but these impacts appear to vary from wind plant to wind plant.

Two types of local impacts to birds have been demonstrated at existing wind plants: 1) direct mortality from collisions, and 2) indirect impacts from avoidance, habitat disruption and displacement. Direct impacts to bats have also been documented at some wind plants.

Direct Mortality

- Birds and bats sometimes die in wind farms as a result of collisions with wind turbines, meteorological towers (and their supporting guy wires), and with maintenance vehicles traveling the project roads.
- Both migrating birds and resident birds sometimes collide with wind turbines.
- The annual number of raptor deaths at Altamont Pass, California, which has over 5000 older and smaller turbines and high raptor use, is higher than at other wind farm sites where monitoring of fatalities has been conducted. Compared with other avian species studied to date throughout the United States, some species such as raptors (including hawks, golden eagles, falcons and owls) appear to be at higher risk relative to their occurrence of collisions with wind turbines. The reason for this higher frequency of collisions, relative to other species, is not fully understood.
- As indicated by experience at more recent projects, a pre-development site evaluation conducted at a potential wind site can help determine whether wind power development at that site is likely to cause avian and bat impacts at levels of concern. Such evaluations with respect to the site can include assessments of relevant existing information, physical inspections, and direct observational and technological methodologies designed to document levels of bird and bat use and behavior. One application of

the site evaluation is for use in designing a less-impacting project.

- Most fatality estimates reported for wind projects are based on extrapolations of the number of fatalities with the estimates corrected for observer detection, scavenging, and other sampling biases. The larger the correction factors, the higher the uncertainty in the estimates. Some factors affecting the size of the correction factors and uncertainty and potential biases in the estimates include frequency of searches (e.g., daily, weekly, monthly), number of turbines searched, distances between search transects, search area (e.g., 100 m from turbine, 50 m from turbine), habitat types, and observer abilities. Careful assessment of these factors is critical to the understanding and reduction of both the potential biases and the uncertainty in the estimates.

- Fatality rates of birds vary among sites and likely depend on several factors including: the amount of bird use, vegetation, and other physical and biological characteristics of the specific wind plant and surrounding area. There were approximately 6,400 MW, about 12,000 turbines, of installed wind generation capacity at the end of 2003 in the US, with about 4,300 MW, about 4,700 turbines (almost all newer and larger), located outside California. Fatality estimates adjusted for searcher efficiency and scavenging bias have been reported for 12 wind projects outside California. Based on these 12 studies, the fatality rate averages 2.3 per turbine per year and 3.1 per megawatt per year of capacity in the U.S. outside of California (Table 1). The fatality rates have ranged from a low of 0.63 per turbine and 1 per megawatt at an agricultural site in Oregon to 10 per turbine and 15 per megawatt at a fragmented mountain forest site in Tennessee.[2] For information on raptors see Table 2.

- There have been no documented large fatality events[3] of songbirds at wind projects. The two largest events reported include 14 spring migrant songbirds found at two adjacent turbines in Minnesota on one night and approximately 30 spring migrant songbirds at a floodlit substation and nearby turbines in West Virginia on one night during foggy weather.

Indirect Impacts

- Studies have demonstrated generally that there are two significant factors important in assessing risk to birds; the level of use at the site and the behavior of the birds at the site.

- Several studies have been published or are ongoing on the displacement and avoidance impacts of wind turbines and associated infrastructure and activities on grassland and shrub-steppe breeding songbirds and other open country birds (prairie and sage grouse, shorebirds, waterfowl, etc.). Some of these studies have documented decreased densities of and avoidance by grassland songbirds and other birds as a function of distance to wind turbines and roads. The level of impact varies by species, and ongoing research is quantifying the distance of avoidance caused by the presence of infrastructure and human activity. Some birds seem to adapt (habituate) to areas previously avoided.

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[2]Note: Caution must be used when comparing per-turbine fatality data among wind projects, especially between modern wind projects (built in 1998 or later) and older wind projects, nearly all of which are located in California. Per-turbine fatality rate comparisons may be misleading because older turbines are much smaller in size, and their per-turbine fatality rates will appear lower for that reason. For example, the most common turbine at the Altamont Pass is a 100-kW turbine, while most new wind projects are being developed with 1-MW or larger turbines. A more comparable metric among turbine sizes would be on a per-MW or a per-unit of rotor swept area basis. At this time, per-MW and per-unit of rotor swept area basis give approximately the same results.

[3]*Large scale fatality events* in the ornithological literature generally refer to single, one-night collision events usually involving hundreds to thousands of birds at a single structure such as a tall communication tower or light house. These events are distinct from cumulative fatalitie accrue from single or small numbers of fatalities that occur over many days/nights at many structures.

Table 1. **Regional and Overall Bird Fatality Rates. Fatality Rates Estimated Based on Number of Fatalities found, and Adjustments for Scavenging and Observer Detection Biases**[1,2]

Region	# studies	# MW	Rotor Diameter (m) min	Rotor Diameter (m) max	# birds/turbine/year avg	# birds/turbine/year min	# birds/turbine/year max	# birds/MW/year avg	# birds/MW/year min	# birds/MW/year max
Northwest	4	397	47	65	1.9	0.6	3.6	2.7	0.9	2.9
Rocky Mts.	2	68	42	44	1.5	1.5	1.5	2.3	2.0	2.5
U. Midwest	4	254	33	48	2.7	1.0	4.5	4.2	2.0	5.9
East	2	68	47	72	4.3	4.0	7.7	3.0	2.7	11.7
Overall	12	787	33	72	2.3	0.6	7.7	3.1	0.9	11.7

[1] Based on studies of wind projects that were conducted for a minimum of 3 seasons (spring, summer and fall), and where scavenging and searcher efficiency biases were incorporated into the estimates. Per-turbine estimates are weighted by number of turbines at projects studied, Per-MW estimates by number of MW at projects studied.
[2]We are only aware of two California studies that reported estimates for all birds apparently adjusted for scavenging and searcher efficiency. One estimate was 2.3 birds/turbine at San Gorgonio, where nearly all of the turbines studied were small (65-200 kW), and methods for scavenging and searcher efficiency adjustments are unknown. A recent estimate from Altamont Pass for mostly small turbines (200 kW and less) was 8.1/MW/year, using bias adjustments from a study in the Pacific Northwest.

Table 2. **Regional and Overall Raptor Fatality Rates. Fatality Rates Estimated Based on Number of Fatalities found, and Adjustments for Scavenging and Observer Detection Biases** [1]

Region	# studies	# MW	Rotor Diameter (m) Min	Rotor Diameter (m) max	#raptors/turbine/year avg	#raptors/turbine/year min	#raptors/turbine/year max	#raptors/MW/year avg	#raptors/MW/year min	#raptors/MW/year max
Newer Generation Projects										
Northwest	4	397	47	65	0.05	0.00	0.07	0.07	0.00	0.09
Rocky Mts.	2	68	42	44	0.03	0.03	0.04	0.05	0.05	0.06
U. Midwest	4	254	33	48	0.00	0.00	0.01	0.00	0.00	0.04
East	2	68	47	72	0.02	0.00	0.02	0.01	0.00	0.02
Overall	12	787	33	72	0.03	0.00	0.07	0.04	0.00	0.09
California[2]	3	~878	15	33	0.15	0.01	0.24	1.37	<0.1	2.24

[1] Table 2 is based on studies of wind projects that were conducted for a minimum of three seasons (spring, summer and fall). Per-turbine estimates are weighted by number of turbines at projects studied, Per-MW estimates by number of MW at projects studied.
[2]Data at older turbines in CA; based on most recent publication from the Altamont, and older studies at Montezuma Hills and San Gorgonio, where methods are less understood.

Table 3. **Regional and Overall Bat Fatality Rates. Fatality Rates Estimated Based on Number of Fatalities Found, and Adjustments for Scavenging and Observer Detection Biases** [1,2]

Region	# studies	# MW	Rotor Diameter (m) min	Rotor Diameter (m) max	#bats/turbine/year avg	#bats/turbine/year min	#bats/turbine/year max	#bats/MW/year avg	#bats/MW/year min	#bats/MW/year max
Northwest	4	397	47	65	1.2	0.7	3.2	1.7	0.8	2.5
Rocky Mts.	2	68	42	44	1.2	1.0	1.3	1.9	1.3	2.2
U. Midwest	4	254	33	48	1.7	0.1	4.3	2.7	0.2	6.5
East[3]	2	68	47	72	46.3	28.5	47.5	32.0	31.7	43.2
Overall	12	787	33	72	3.4	0.1	47.5	4.6	0.9	43.2

[1] Table 3 is based on studies of wind projects that were conducted for a minimum of three seasons (spring, summer and fall), and where scavenging and searcher efficiency biases were incorporated into the estimates, although most bias trials used birds to represent bats in the trials. Per-turbine estimates are weighted by number of turbines at projects studied, Per-MW estimates by number of MW at projects studied.
[2] A few bat fatalities have been reported at older projects in California, but no estimates have been made.
[3] Improved estimates expected in winter 2004/2005 from intensive fall 2004 studies at two sites.

WHAT IS LESS UNDERSTOOD?

Birds

- Turbine Size and Avian Risk: It is not yet clear whether larger (i.e., 750 KW to 2+ MW) or smaller (i.e., 40 kW to 400 kW) wind turbines cause equivalent bird collision fatalities based on rotor swept area or megawatts of generating capacity. Furthermore, results may differ among species groups (migrants versus residents, songbirds versus raptors, within and between seasons and years).
- Impacts of Lighting: Questions remain about the impact of facility lighting on night migration of songbirds and other nocturnally flying birds, particularly during poor weather conditions. Studies at communication towers and some other lit structures suggest birds may become disoriented in poor weather, and are attracted to lights, which may increase their vulnerability to collisions with towers, guy wires and turbine blades. The number of turbines lit and types of lighting have varied at existing projects as well as associated facilities. Further studies are needed to better understand the effects of light color, type, duration on, and intensity.
- Tower Design and Avian Risk: Wind turbines are either built on "lattice" (built of interlocking steel members, like "Erector set" pieces) or tubular (built of large sections of steel pipe) towers. Study results are inconclusive regarding whether tower design is a risk factor for collision fatalities.
- Impacts of Wind Turbines on Songbirds: The full impact of wind turbines on resident and migrating songbirds is not clear. Songbird kills have been recorded as part of wind bird studies since the first studies were performed in the early 1980's. In many areas the number of night migrating birds is enormous, but there have been few recorded deaths. Because scavengers and other activities such as field plowing and crop harvesting remove some carcasses and because searchers do not detect all carcasses, it is essential that carcass removal and searcher detection rates be incorporated when estimating total fatalities. Monitoring direct impacts and assessing factors influencing the ability to locate carcasses is becoming increasingly common in the industry. Songbird impacts must be considered for each wind development.
- Impacts of Wind Development on Prairie and Sage Grouse: At this time, there are no completed studies of impacts, including at a population level, of wind turbines and associated facilities on prairie grouse. Other research has shown that habitat fragmentation and human disturbances from roads, houses, and other large structures impact habitat suitability to varying degrees for various species of prairie grouse. Habitat loss and fragmentation have been raised as critical issues in the survival of prairie grouse populations. While there is no evidence that individual wind projects are likely to result in significant population effects, it is important to evaluate the cumulative impacts of wind power and other land use changes in relation to prairie grouse habitat carrying capacity and the viability of individual grouse populations.
- Impact of Weather Events on Bird Deaths: Birds may become disoriented in poor weather, and may be forced to fly at lower altitudes during migration due to heavy overcast weather, increasing the number of birds potentially flying through wind plants, especially when light attraction may be an issue.

Bats

- Impacts of Wind Turbines on Bats: In assessing avian mortality at wind turbine sites around the country, most researchers also collect data on bat collision mortality, although the data may not necessarily be published or be made publicly available. Research currently indicates that bats suffer collision fatality at some level (Table 3) and a large percentage of the incidents have occurred during the fall migratory period. As with bird counts, carcass removal and searcher efficiency need to be included in fatality estimates. Research and analysis are being conducted to further assess wind turbine impacts on bats and more clearly understand why bats collide.

- Bat kills at Appalachian Mountain ridgetop turbines are a newly reported phenomenon. Prior to 2003, 85 bats had been reported killed at 3 turbines at Buffalo Mountain, Tennessee, constituting the only noteworthy mortality in the Eastern U.S. However, 458 bats of 7 species were found killed at 44 turbines at a West Virginia wind project in 2003. Extrapolation from this number, using surrogate scavenging and searcher efficiency data from birds, suggests the number of actual kills was likely far higher (~2,100 with a wide range of uncertainty). As significant additional wind development is planned in this area, overall bat impacts have the potential to become very substantial. To address these challenges, bat experts from the U.S., Canada, and Great Britain met in February, 2004, and a cooperative research effort to understand and deter bat mortality, with industry, government, and private donor funding, is now underway. Because so little is known about bat behavior, movement and migration, night-vision and thermal-imaging equipment, echolocation detectors, and marine radars have all been identified as tools that may help assess the problems

AREAS WHERE STUDIES ARE ONGOING OR WHERE NEW INSIGHTS MAY EMERGE

- Research is continuing in Altamont Pass to better understand the issues there and determine what, if any prevention or mitigation measures can be implemented to reduce fatalities.

- "Repowering" in Altamont Pass offers the potential to evaluate the difference between early-generation and modern wind turbines with respect to avian issues.

- Basic research is continuing on avian vision, hearing, and other issues that may yield information on how to reduce wind plant risk to birds.

- Research is continuing on the risk to nocturnal migrating birds from wind plants constructed on high mountain top ridges in the U.S. The uncertainty surrounding the potential risk to birds from these wind plants is caused in part by uncertainty regarding the behav 6 nocturnal migrating birds, an particular how migration is influenced by wind flow over mountainous terrain changes. Some scientists have hypothesized that nocturnal migrants in mountainous terrain fly at a relatively low altitude above ground level (AGL), turning at and/or following ridges that run roughly parallel to the axis of migration. Some also believe that nocturnal migrants do not gain significant altitude when forced to fly over high ridges perpendicular to the axis of migration. Both behaviors would result in birds concentrating at a relatively low AGL above ridge tops.

Either behavior would increase risk of collisions with wind turbines placed on ridge tops. Other scientists believe that most nocturnal migrating birds migrate at elevations above today's typical turbine heights and that most topographical relief has little influence on migration behavior. Airport and weather radar studies support the latter hypothesis. Recent studies using horizontal and vertical marine radar units in tandem, which are suited to making direct measurements of flight heights up to several thousand meters, also support the latter hypothesis in the western U.S. Research using this type of radar methodology and other technologies, for example acoustics, in the eastern U.S. and ongoing fatality monitoring data at existing sites will improve our understanding of the effect of topography on bird migration and our ability to assess the risk to nocturnal migrants from existing and proposed wind plants on mountain ridges. It has been suggested that migrant songbirds may be at risk of collision during morning landings and evening departures, especially during inclement weather conditions, when they land to rest and feed during the daytime. However, there is no data at present to support this hypothesis.

End Note on Applicable Laws:

Migratory Bird Treaty Act (16 U.S.C. 703-712): the cornerstone of migratory bird conservation and protection in the U.S., the Act implements 4 bilateral treaties that provide for international protection of 836 species of migratory birds. MBTA is a strict liability statute wherein proof of intent is not an element of a taking violation. The Act prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Department of Interior. "Accidental" or "incidental" take permits are not issued by the U.S. Fish & Wildlife Service which administers the Act. A violation of MBTA by an individual or organization can result in a fine of up to $15,000 and/or imprisonment for up to 6 months for a misdemeanor, and up to $250,000 and/or imprisonment for up to 2 years for a felony. The Service's Office of Law Enforcement carries out its mission to protect migratory birds not only through investigations and enforcement, but also through fostering relationships with individuals and industries that proactively seek to eliminate their impacts on migratory birds. While it is not possible under the Act to absolve individuals, companies, or agencies from liability if they follow, for example, recommended wind turbine guidelines, the Office of Law Enforcement and Department of Justice have used enforcement and prosecutorial discretion in the past regarding individuals, companies, or agencies who have made good faith efforts to avoid the take of migratory birds.

Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d) is another strict liability statute which affords Bald and Golden Eagles additional legal protection. Penalties for violations of BGEPA are up to $250,000 and/or 2 years imprisonment for a felony, with fines doubled for an organization.

Endangered Species Act (16 U.S.C. 1531-1544) was implemented to protect endangered and threatened species and to provide a means to conserve their habitats. The law is administered by the USFWS and the Commerce Department's National Marine Fisheries Service. USFWS has primary responsibility for terrestrial and fresh-water organisms. Where turbines are proposed for siting on Federal lands, or where Federal funding or Federal licensing permits are involved, the Federal agency involved must consult with USFWS under Section 7. Section 10 allows for the development of "Habitat Conservation Plans" for listed species on private lands. This provision is designed to assist private landowners in incorporating conservation measures for listed species on their land and/or water development plan. Private landowners who develop and implement a USFWS-approved habitat conservation plan can receive an incidental take permit that allows the development to go forward. Section 9 makes it unlawful to take a listed species, defining take as "...to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any of such conduct." The term harm, defined through regulations, is "an act which actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, and sheltering." As previously discussed, permits for "incidental take" can be issued under Section 10 (not to be confused with MBTA where "incidental take" permits are not issued).

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