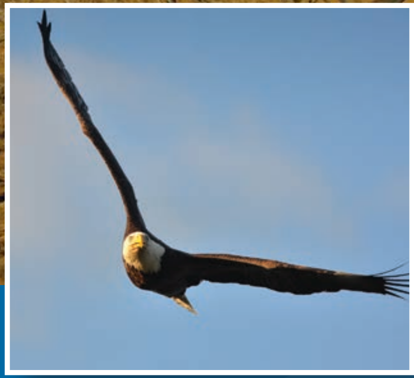
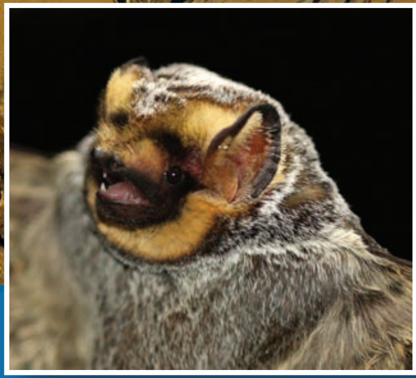
Wind Turbine Interactions with Wildlife and their Habitats

A Summary of Research Results and Priority Questions

Last Updated with Latest Publicly Available Information: June 2016

This fact sheet summarizes publicly available information about the adverse impacts of land-based wind power on wildlife in North America and the status of our knowledge regarding how to avoid or minimize these impacts.

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BACKGROUND: DRY LAKE WIND POWER PROJECT, PHOTO BY IBERDROLA RENEWABLES, INC., NREL • INSET, L-R: EASTERN MEADOWLARK, PHOTO BY MATTHEW PAULSON, FLICKR • AMERICAN BALD EAGLE, PHOTO BY USFWS, FLICKR • HOARY BAT, PHOTO BY J. N. STUART, FLICKR

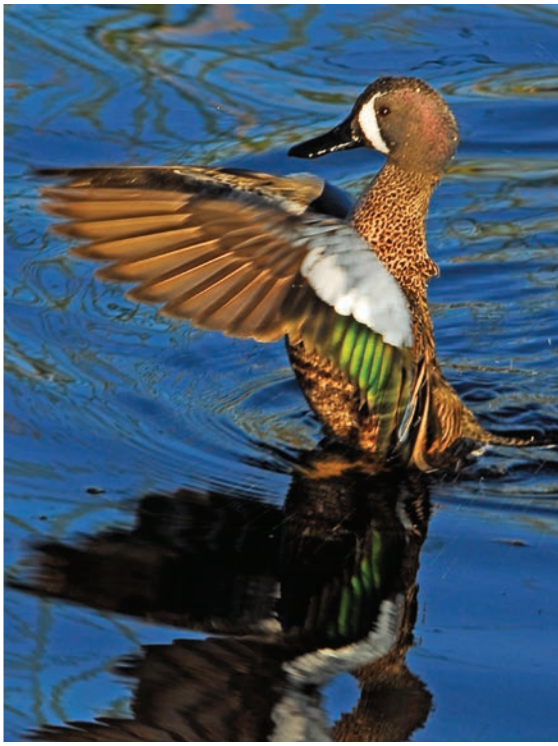
SMOKY HILLS WIND FARM, PHOTO BY DRENALINE, WIKIPEDIA

INTRODUCTION

Wind energy's ability to generate electricity without carbon emissions is expected to reduce the risk of potentially catastrophic effects to wildlife from unmitigated climate change. Wind energy also provides several other environmental benefits including substantially reduced water withdrawals and consumption and decreased emissions of mercury and other sources of air and water pollution associated with the burning of fossil fuels (NRC 2010).

The siting and operation of wind energy facilities also present a risk of adverse impacts to wildlife. While effects on wildlife populations have not been measured (e.g., NAS 2007), adverse impacts of wind energy facilities to wildlife have been documented, particularly to individual birds and bats (Arnett et al. 2008; Strickland et al. 2011). The potential for biologically significant impacts to wildlife continues to be a source of concern as populations of many species overlapping with proposed wind energy development are experiencing long-term declines as a result of habitat loss and fragmentation, disease, non-native invasive species, and increased mortality from numerous other anthropogenic activities (e.g., NABCI 2009; Arnett and Baerwald 2013).

In order to maximize wind energy's benefits while addressing the risk to wildlife, a first step is to better understand the extent of the risk and impact of wind energy development to wildlife. This fact sheet summarizes publicly available information about the adverse impacts of land-based wind power on wildlife in North America and the status of our knowledge regarding how to avoid or minimize these impacts.



BLUE-WINGED TEAL, PHOTO BY ANDREA WESTMORELAND, FLICKR

The amount of research in the peer-reviewed literature continues to grow, reflecting the continued interest in understanding wind-wildlife interactions. In order to maintain the highest level of scientific rigor for this fact sheet, we have emphasized research that has been published in peer-reviewed journals as well as un-published, publicly available reports that have undergone expert, technical review.

In recognition of the active work in this field of research, this fact sheet is updated and undergoes expert review on an annual basis to incorporate new results as they become publicly available. Literature citations supporting the information presented are denoted in parentheses; full citations can be found online at http://awwi.org/resources/summary-of-wind-wildlife-interactions/.

Organization of this Fact Sheet

Individual birds and bats may die as a result of collisions with wind turbines. Some species also experience additional adverse impacts, including direct and indirect habitat loss from the construction and operation of wind energy facilities. Indirect effects include displacement by avoidance of otherwise suitable habitat and demographic impacts such as reduced survival or reproductive output (e.g., Arnett et al. 2007; Kuvlesky et al. 2007; NAS 2007; Strickland et al. 2011). This fact sheet organizes statements about what is known and what remains uncertain regarding the adverse impacts of wind energy on wildlife in the following categories:

- Direct mortality
- Cumulative impacts of mortality and population level consequences of collision fatalities
- Avoidance and minimization of collision fatalities
- Direct and indirect habitat-based impacts

Within each section, statements are ordered in decreasing level of certainty. Our level of certainty reflects the "weight of the evidence" from multiple studies on a question of interest. A single published study, although informative, is usually insufficient for drawing broad conclusions. For example, fatality monitoring for birds and bats has been conducted for many years and has become a routine procedure at new facilities.[1] Although more information is available on direct impacts to individuals, substantial uncertainty remains about our understanding of the population-level consequences of collision mortality and our ability to predict collision risk.

1 To demonstrate adherence to the 2012 USFWS Land-based Wind Energy Guidelines, project operators are requested to conduct a minimum of two years of post-construction fatality monitoring.

Installed wind energy capacity in the United States continues to grow and was estimated at approximately 74,000 megawatts (MW) at the end of 2015. Land-based wind turbines have grown substantially in power output over the years; the power rating of turbines installed at new projects ranges from 1.5-3.0 MW. Modern turbine towers range in height from 200–260 feet (60-80 m) and turbine blades create a rotor swept area of 75-130 m (250–425 feet) in diameter, resulting in blade tips that can reach over 140 m (460 feet) above ground level. Rotor swept areas now exceed 0.4 ha (one acre) and are expected to reach nearly 0.6 ha (1.5 acres) within the next several years. The speed of rotor revolution has significantly decreased from 60-80 revolutions per minute (rpm) to 11–28 rpm, but blade tip speeds have remained about the same; ranging from 220-290 km/hr (140-180 mph) under normal operating conditions. Most modern wind energy facilities have fewer machines and larger turbines producing the same or more electricity than early facilities; current projects have wide spacing between turbines and cover thousands of acres. The most current wind market information can be found at the American Wind Energy Association's website.

WOODWARD MOUNTAIN WIND RANCH, PHOTO BY TODD SPINK, NREL 11283

DIRECT MORTALITY

The number of studies reporting results of collision fatality monitoring at operating land-based wind energy facilities has increased substantially over the years, and nearly 170 studies conducted at nearly 100 projects are publicly available (e.g., Arnett and Baerwald 2013; Loss et al. 2013a; Erickson et al. 2014). Protocols for carcass searches have become more standardized, facilitating comparisons of results from separate studies. Much uncertainty remains as to the distribution, timing, and magnitude of collision fatalities in both birds and bats. Some of this uncertainty reflects the lack of data from particular regions of the country. For example, there are only a few publicly available fatality reports from the southwestern U.S., and the northern and eastern regions of the country are underrepresented relative to the Midwest/prairie, the Pacific Northwest, and California. It is also unknown whether publicly available reports are representative of what is occurring at the facilities in regions from which data are not currently available.

This first section briefly outlines what is known and where there is remaining uncertainty about the patterns of collision fatalities, particularly in the continental U.S. We first examine patterns that apply to both birds and bats and then describe patterns for birds and bats separately.

BLACK THROATED BLUE WARBLER, PHOTO BY KELLY COLGAN AZAR, FLICKR

LITTLE BROWN BATS, PHOTO BY USFWS, FLICKR

Fatalities of birds and bats have been recorded at all wind energy facilities for which results are publicly available.

We assume that most bird and bat collisions are with the rotating turbine blades (Kingsley and Whittam 2007; Kunz et al. 2007; Kuvlesky et al. 2007; NAS 2007; Arnett et al. 2008; Strickland et al. 2011), although collisions with turbine towers are also possible. Fatality rates from most studies range from three to five birds per MW per year[2] for all species combined and adjusted for detection biases (e.g., Strickland et al. 2011, Loss et al. 2013a, Erickson et al. 2014); no study has reported more than 14 bird fatalities per MW per year (e.g., Strickland et al. 2011). There is relatively little variation in bird fatalities across regions for all species combined, although fatalities at sites in the Great Plains appear to be lower than sites in the rest of the U.S., and fatalities in the Pacific region may be significantly higher (Loss et al. 2013a). It is unknown to what extent these differences reflect the sample bias discussed earlier.

Bat fatality rates can be substantially higher than bird fatality rates, especially at facilities in the upper Midwest and eastern forests: two facilities within the Appalachian region reported fatality levels of greater than 30 bats/MW per year, but there are also reports as low as one to two bats/MW per year at other facilities in the eastern U.S. (e.g., Hein et al. 2013). Studies have not found a consistent pattern of fatalities across landscape types: fatality rates can be equally high in agricultural or forested landscapes, or in a matrix of

2 Fatality rates are typically reported on a per turbine basis or on the basis of nameplate capacity (MW). We report fatality rates on the basis of nameplate capacity to account for differences in turbine capacity, which range from 100 kw to 2.5 MW or more, but we acknowledge that this reporting format also has difficulties.

those landscape types (e.g. Jain et al. 2011). Fatality rates average substantially lower at facilities in the western U.S. (Arnett et al. 2013a; Hein et al. 2013).

The lighting currently recommended by the Federal Aviation Administration (FAA) for installation on commercial wind turbines does not increase collision risk to bats and migrating songbirds.

The number of bat and songbird fatalities at turbines using FAA-approved lighting is not greater than that recorded at unlit turbines (Avery et al. 1976; Arnett et al. 2008; Longcore et al. 2008; Gehring et al. 2009; Kerlinger et al. 2010). One study recorded higher red bat fatalities at unlit turbines compared to those using red aviation lights; no differences were observed for other bat species between lit and unlit turbines (Bennett and Hale 2014). The FAA regulates the lighting required on structures taller than 199 feet in height above ground level to ensure air traffic safety. For wind turbines, the FAA currently recommends strobe or strobe-like lights that produce momentary flashes interspersed with dark periods up to three seconds in duration, and they allow commercial wind facilities to light a proportion of the turbines in a facility (e.g., one in five), firing all lights synchronously (FAA 2007). Red strobe or strobe-like lights are frequently used.

The effect of turbine height and rotor swept area on bird and bat collision fatalities remains uncertain.

Some studies have indicated that collisions increase with wind turbine tower height on a per MW basis (e.g., Baerwald and Barclay 2009; Barclay et al. 2007; Arnett and Baerwald 2013), but there is conflicting evidence for birds, suggesting that the relationship between tower height and bird collisions is more nuanced (Smallwood and Karas 2009; Loss et al. 2013a). Taller turbines often have much larger rotor-swept areas, and it has been hypothesized that collision fatalities will increase due to the greater overlap with flight heights of nocturnal-migrating songbirds and bats (Johnson et al. 2002; Barclay et al. 2007). The vast majority (>80%) of avian nocturnal migrants typically fly above the height of the most common rotor-swept zone (<500 feet; <150 m) (Mabee and Cooper 2004; Mabee et al. 2006).

GRASSHOPPER SPARROW, PHOTO BY SHEILA GREGOIRE, FLICKR

It is unknown whether collision risk at single towers is comparable to risk at individual towers within large wind energy facilities.

Construction of single utility-scale turbines (1.5-2 MW) is growing rapidly in some regions of the country, especially where opportunities for large utility-scale projects are limited or municipalities often supply their own electricity (e.g., Massachusetts). Fatality monitoring at single turbine facilities is often not required, and published reports have not been available.

PEETZ TABLE WIND FARM; PHOTO BY MARGUERITE KELLY, NREL 14112

GOLDEN-CROWNED KINGLET, PHOTO BY ZANATEH, FLICKR

Birds

A substantial majority of bird fatalities at wind energy facilities are small passerines.

Approximately 250 species of birds have been reported as collision fatalities at wind energy facilities for which data are available (e.g., Loss et al. 2013; Erickson et al. 2014). Based on available data, collisions of small passerines (<31 cm in length) account for approximately 60% of fatalities at U.S. wind facilities (e.g., Erickson et al. 2014); small passerines comprise more than 90% of all landbirds (Partners in Flight Science Committee 2013). Most small passerine species are migratory, resulting in spring and fall peaks of bird casualty rates at most wind facilities (Strickland et al. 2011).

Diurnal raptors and pheasants are also relatively frequent fatalities, particularly in the western U.S. where these species are more common. These groups are far less abundant than passerines, and the relatively high fatality rates for raptors and pheasants suggest a higher vulnerability to collision. The vulnerability to collision of native game birds (e.g., sage grouse and prairie chickens) is unknown. Fatalities of waterbirds and waterfowl, and other species characteristic of freshwater, shorelines, open water and coastal areas (e.g., ducks, gulls and terns, shorebirds, loons and grebes) are recorded infrequently at land-based wind facilities (e.g., Kingsley and Whittam 2007; Gue et al. 2013), although this could change as more development occurs offshore or in regions where waterfowl abundance is high (e.g., Graf et al. 2016). The infrequent rate of fatalities of coastal birds is somewhat different than that reported at coastal facilities in the Netherlands (e.g., Winkelman 1992; Stienen et al. 2008; Everaert 2014), but this could be owing to the limited information from coastal wind facilities, particularly in the U.S. (Kingsley and Whittam 2007; NAS 2007).

Newer, larger (≥500 kW) turbines may reduce raptor collision rates at wind facilities compared to older, smaller (40 - 330kW) turbines.

The number of raptor fatalities on a per MWh basis appear to be declining substantially (67–96% depending on the

GOLDEN EAGLE, PHOTO BY ELSIE.HUI, FLICKR species) at the Altamont Pass Wind Resource Area as a result of repowering; smaller, low-capacity turbines are being replaced with taller, higher-capacity turbines (Smallwood and Karas 2009). Larger turbines have fewer rotations per minute, which may be partly responsible for lower raptor collision rates (NAS 2007). In addition, smaller turbines that use lattice support towers offer more perching sites for raptors, encouraging higher raptor occupancy in the immediate vicinity of the rotor swept area (NAS 2007) than large, modern turbines on tubular support towers.

Bats

Migratory tree-roosting bat species are vulnerable to colliding with wind turbines.

At least 21 species of bats have been recorded as collision fatalities, but the majority of fatalities reported to date are from three migratory tree-roosting species (the hoary bat, the Eastern red bat, and the silver-haired bat) which collectively constitute almost 80% of the reported fatalities at wind facilities for all North American regions combined (NAS 2007; Kunz et al. 2007; Arnett et al. 2008; Arnett and Baerwald 2013; Hein et al. 2013).

It is unclear to what extent this conclusion reflects sample bias as there are few reports available from the southwestern U.S. (especially Texas and Oklahoma where there is high installed wind capacity) where a very different bat fauna is present than at most other facilities in the U.S. Higher percentages of cave dwelling bats have been recorded at wind energy facilities in the Midwest compared to other facilities in the U.S. (e.g., Jain et al. 2011), and the few available studies indicate that Brazilian free-tailed bats can constitute a substantial proportion (41–86%) of the bats killed at facilities within this species' range (Arnett et al. 2008; Miller 2008; Piorkowski and O'Connell 2010). However, it is uncertain whether this species is at greater risk than other species because the Brazilian free-tailed bat is a very abundant species where it occurs.

Bat fatalities peak at wind facilities during the late summer and early fall migration.

Several studies have shown a peak in bat fatalities in late summer and early fall, coinciding with the migration season of tree bats (Kunz et al. 2007; Arnett et al. 2008; Baerwald and Barclay 2011; Jain et al. 2011), and a smaller peak in fatalities during spring migration has been observed for some bat species at some facilities (Arnett et al. 2008).

Some bat species may be attracted to wind turbines.

It has been hypothesized that the relatively high number of recorded fatalities of migratory tree bats may be explained by attraction to wind turbines (e.g., Horn et al. 2008); several factors that might attract these bats have been proposed, including sounds produced by turbines, a concentration of insects near turbines, and bat mating behavior (Kunz et al. 2007; Cryan 2008; Cryan and Barclay 2009). Infrared imagery has shown bats exploring the nacelles of wind turbines from the leeward direction, especially at low wind speeds (Cryan et al. 2014). Analysis of bat carcasses beneath turbines found large percentages of mating readiness in male hoary, eastern red, and silver-haired bats, indicating that sexual readiness coincides with the period of high levels of fatalities in these species (Cryan et al. 2012).

EASTERN RED BAT, PHOTO BY MATTHEW O'DONNELL, FLICKR

Barotrauma does not appear to be an important source of bat mortality at wind energy facilities.

Forensic examination of bat carcasses found at wind energy facilities suggests that the importance of barotrauma, i.e., injury resulting from rapidly altered air pressure caused by fast-moving wind turbine blades (see Baerwald et al. 2008) is substantially less than originally suggested (Rollins et al. 2012; see also Grodsky et al. 2011). The barotrauma hypothesis remains inadequately tested at this time.

HOARY BAT, PHOTO BY DANIEL NEAL, FLICKR

Weather patterns may influence bat fatalities.

Bat activity is influenced by nightly wind speed and temperature (Weller and Baldwin 2012), and some studies indicate that bat fatalities occur primarily on nights with low wind speed and typically increase immediately before and after the passage of storm fronts. Additional research on weather patterns as a predictor of bat activity and fatalities could support mitigation efforts to reduce bat fatalities (Arnett et al. 2008; Baerwald and Barclay 2011; Weller and Baldwin 2012; Arnett and Baerwald 2013).

It is uncertain whether bat fatalities in migratory tree bats are male-biased.

Examination of external characteristics of bat carcasses collected at wind energy facilities indicated that the sex ratio of migratory tree bats was skewed towards males (e.g., Arnett et al. 2008), although other studies had shown female-bias or no bias (e.g., Baerwald and Barclay 2011). Bats can be a challenge to age and sex from external characteristics, especially when carcasses have decomposed or have been partially scavenged. Molecular methods used to sex bat carcasses indicate that sex ratios in fatalities of tree bats are not male-biased, although male bias in fatalities may persist in other species (e.g., evening bat, Korstian et al. 2013).

CUMULATIVE IMPACT OF BIRD AND BAT COLLISIONS

The estimated total number of bird collision fatalities at wind energy facilities is several orders of magnitude lower than other leading anthropogenic sources of avian mortality.

Several recent estimates indicate that the number of birds killed at wind energy facilities is a very small fraction of the total, annual human-related bird mortality and two to four orders of magnitude lower than mortality from other sources of human-related mortality, including feral and domestic cats, power transmission lines, buildings and windows, and communication towers, (NAS 2007; Longcore et al. 2012; Calvert et al. 2013; Loss et al. 2014a,b,c; Loss et al. 2013a,b; Erickson et al. 2014).

Fatality rates at currently estimated values do not appear likely to lead to population declines in most bird species.

For small passerine species, current turbine-related fatalities constitute a very small percentage of their total population size, even for those species that are killed most frequently (typically <0.02%; Kingsley and Whittam 2007; Kuvlesky et al. 2007; NAS 2007; Erickson et al. 2014). As wind energy development expands, the potential for biologically significant impacts to some populations of species, such as raptors, may increase (NAS 2007; Johnson and Erickson 2010).

The status of bat populations is poorly known and the ecological impact of bat fatality levels is not known.

Bats are long-lived and some species have relatively low reproductive rates, making populations susceptible to localized extinction (Barclay and Harder 2003; Jones et al. 2003). Population sizes for migratory tree bat species are unknown,

HORNED LARK, PHOTO BY KENNETH COLE SCHNEIDER, FLICKR

DILLON WIND POWER PROJECT, PHOTO BY IBERDROLA RENEWABLES, INC., NREL 16105

and we don't know whether current or future collision fatality levels represent a significant threat to these species (NAS 2007; Kunz et al. 2007; Arnett et al. 2008; Arnett and Baerwald 2013). Studies have focused on estimating effective population sizes from genetic data, and these estimates might be useful as baselines for evaluating future impacts of collision mortality and other threats to bats (Korstian et al. 2015; Vonhof and Russell 2015; Sovic et al. 2016).

The ecological implications of White-Nose Syndrome and collision fatalities for bats are not well understood.

White-Nose Syndrome (WNS) is a fungus-caused disease that is estimated to have killed more than six million bats in North America (Frick et al. 2010; Turner et al. 2011; Hayes 2012). Cave-dwelling bats are most at risk, and it is unknown whether WNS will be a significant source of mortality in migratory tree bats that appear to be most vulnerable at wind energy facilities. Migratory tree bats rarely occur in caves and their solitary nature may not facilitate the spread of fungal spores (e.g., Foley et al. 2011). Because cave-dwelling bats represent a higher percentage of fatalities at Midwestern wind energy facilities, there is concern about the added mortality of wind turbine collisions to WNS-vulnerable bat species in this region. Fatality rates in these species actually could decline, because population sizes are being reduced by WNS, although the relationship between bat abundance and collision risk has not been established.

AVOIDING AND MINIMIZING BIRD AND BAT FATALITIES

Siting

Substantial effort is made to estimate collision risk of birds and bats prior to the siting, construction, and operation of wind energy facilities under the premise that high-activity sites will pose an unacceptable risk to these species and should be avoided. Many wind energy companies choose to apply a tiered decision-making process as outlined in the Land-based Wind Energy Guidelines issued by the U. S. Fish and Wildlife Service in 2012. This approach, developed with input from multiple stakeholders, outlines a series of steps companies can take to identify potential risk to species thought to be at risk from wind energy development.

There is interest in relating differences in bat fatality rates among wind facilities to landscape characteristics (e.g., topography, landscape types, proximity to landscape features such as mountain ridges or riparian systems). Relating fatality rates to features within the immediate area of a turbine could be useful in siting wind energy facilities and locating turbines within a site to avoid higher-risk areas (Kunz et al. 2007; Kuvlesky et al. 2007; NAS 2007; Arnett et al. 2008).

SILVER-HAIRED BAT, PHOTO BY LASSENNPS, FLICKR

Siting individual turbines away from topographic features that attract concentrations of large raptors may reduce raptor collision fatalities at wind energy facilities.

Some analyses have indicated a relationship between raptor fatalities and raptor abundance (e.g., Strickland et al. 2011; Carrete et al. 2012; Dahl et al. 2012), although studies also suggest that standard activity surveys for raptors may not correlate with fatality rates (Ferrer et al. 2012). Large raptors are known to take advantage of wind currents created by ridge tops, upwind sides of slopes, and canyons that are favorable for local and migratory movements (Bednarz et al. 1990; Barrios and Rodriguez 2004; Hoover and Morrison 2005; de Lucas et al. 2012; Katzner et al. 2012).

The relationship between bird collision risk and bird behavior, especially in the vicinity of the rotor swept area, is complex and not well understood.

Certain species that forage for prey in close proximity to turbines (e.g., red-tailed hawk and golden eagle) appear to have higher fatality rates, while other species that actively fly around wind turbines such as common raven appear to avoid collisions with turbines (Kingsley and Whittam 2007; Kuvlesky et al. 2007; NAS 2007). High prey density (e.g., small mammals) is presumed to be a principal factor responsible for high raptor use and high raptor collision rates at the Altamont Pass wind resource area (Kingsley and Whittam 2007; Kuvlesky et al. 2007; NAS 2007; Smallwood and Thelander 2008).

The ability to predict collision risk for birds and bats from activity recorded by radar and acoustic detectors, respectively, remains elusive.

The use of radar and bat acoustic detectors is a common feature of pre-construction risk assessments for siting wind energy facilities (Strickland et al. 2011). To date, studies have not been able to develop a quantitative model enabling reasonably accurate prediction of collision risk to birds and bats from these surveys (e.g., Hein et al. 2013). Predicting bat collision risk using pre-construction activity measures would be further complicated if bats are attracted to wind turbines (see above).

Operations

Wind energy companies are also employing a variety of technologies and operational techniques to minimize fatalities of vulnerable species at operating wind energy facilities.

RED-TAILED HAWK, PHOTO BY KELLY COLGAN AZAR, FLICKR

Curtailing blade rotation at low wind speeds results in substantial reductions in fatality of bats.

An examination of ten separate studies (Baerwald et al. 2009; Arnett et al. 2011; Arnett et al. 2013b) showed reductions in bat fatalities ranging from 50 to 87% when compared to normally operating turbines. These studies indicate that reductions in bat fatalities were achieved with modest reductions in power production under the conditions at the facilities where experiments were conducted. Further study to identify times when bat collision risk is high could optimize timing of curtailment and minimize power loss (e.g., Weller and Baldwin 2012).

Selective shutdown of high-fatality turbines may be an effective strategy for reducing fatalities of some raptor species.

Some of the highest raptor fatality rates have been observed in southern Spain where raptors congregate to cross the Strait of Gibraltar to Africa during migration (Ferrer et al. 2012). Mortality of griffon vultures at a facility in that area was reduced substantially (mean of 50.8%) by selective shutdown of turbines where the greatest number of fatalities was observed (de Lucas et al. 2012).

The use of ultrasonic transmitters may deter bats away from rotor swept area and reduce bat fatalities, but further testing and enhancement of the technology is needed.

Experimental trials have shown that ultrasonic devices can reduce bat activity and foraging success, and evaluation of similar devices installed on wind turbines has shown some reduction in bat fatalities over control turbines (Arnett et al. 2013a). Development of bat deterrents using both acoustic and visual stimuli remains an active area of research.

Efforts intended to increase turbine visibility and reduce collision fatalities has met with limited success.

Impact minimization methods that are assumed to make turbine blades more visible to birds have been proposed to reduce collisions with wind turbines. For example, it has been hypothesized that towers and blades coated with ultraviolet (UV) paint may be more visible to birds, making them easier to avoid. In the only known test, Young et al. (2003) compared fatality rates at turbines with UV coatings to turbines coated with standard paint and found no difference. Several raptor species have shown little response to ultraviolet light (Hunt et al. 2015). Few data are otherwise available on the effectiveness of these and other potential methods for making turbines more visible to birds.

WHOOPING CRANES, PHOTO BY GILLIANCHICAGO, FLICKR

DIRECT AND INDIRECT HABITAT-BASED EFFECTS OF WIND ENERGY DEVELOPMENT ON BIRDS

Operating wind energy facilities can reduce abundance of some grassland bird species near turbines, but the effect is not consistently observed in all studies.

Studies have shown that the displacement of grassland bird species in response to wind energy development is species-specific and the displacement response of individual species is observed inconsistently (Hatchett et al. 2013; Loesch et al. 2013; Stevens et al. 2013).

It has been suggested that high site fidelity in some grassland bird species may reduce displacement effects in the short-term and displacement would become more pronounced over time, but this has yet to be demonstrated (Strickland et al. 2011). It is also unknown whether bird species will habituate to wind energy facilities and whether disturbance effects diminish over time. In one study, abundance of some species declined during construction of the wind energy facility, but the effect disappeared after the facility became operational (Pearce-Higgins et al. 2012).

GREATER PRAIRIE-CHICKEN, PHOTO BY WILDRETURN, FLICKR

There is concern that prairie chickens and greater sage-grouse will avoid wind energy facilities because of disturbance or because they perceive turbine towers as perches for avian predators.

Research indicates that close proximity to roads, utility poles or lines, trees, oil and gas platforms, and/or human habitations causes displacement in prairie chickens and sage grouse (Robel et al. 2004; Kingsley and Whittam 2007; Kuvlesky et al. 2007). It is hypothesized that similar effects would result from wind energy development, but few published studies have tested this hypothesis (Walters et al. 2014). An extensive and comprehensive multi-year study of greater prairie-chicken in a fragmented Kansas landscape showed neutral, positive, and negative responses to wind energy development as measured by a variety of demographic parameters. There was little or no response in nesting females (Winder et al. 2013; Winder et al. 2014): lek persistence appeared to be lower in proximity to turbines, but there was no detectable effect of turbine proximity on male body mass (Winder et al. 2015). A recently published study found that nest survival and nest success in greater sage-grouse decreased as proximity to turbines increase, but female survival did not differ with distance from turbines (Le Beau et al. 2014).

It is unknown whether wind energy facilities act as barriers to landscape-level movements by big game and other large terrestrial vertebrates.

There is very little information to evaluate the hypothesis that wind energy facilities act as barriers to wildlife. Studies of desert tortoise indicate that wind energy has no negative effect on site use (Lovich et al. 2011; Ennen et al. 2012). Other species for which barrier effects are a concern but for which published research specific to wind energy is not available include pronghorn, mule deer, black bear, and elk (Lovich and Ennen 2013).

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About AWWI

The American Wind Wildlife Institute is a partnership of leaders in the wind industry, wildlife management agencies, and science and environmental organizations who collaborate on a shared mission: to facilitate timely and responsible development of wind energy while protecting wildlife and wildlife habitat. We envision a future where wildlife and wind energy thrive, allowing all of us — wildlife and habitat included — to reap the climate change mitigation benefits that wind energy makes possible.

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