Technical Report

Biology

The Effects of Windfarms on Birds: a Review.

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I. OVERVIEW

Ever since the implementation of wind turbine technology into the energy industry there has been concerns that windfarms are negatively impacting bird life. The most notable of these impacts include fatal and non-fatal collisions, habitat loss and habitat disturbance. Numerous studies in the United States, Canada, Ireland, Germany, Spain and Denmark have shown that windfarms can negatively impact bird life; the impact, however, varies markedly between windfarms. The degree of the impact is a result of the type of area in which the windfarm or wind resource area (WRA) is situated. Areas that are well suited for WRA's – typically areas with high and relatively consistent wind patterns – tend to be areas heavily utilized by birds as migration and dispersal corridors. The result is an increased potential for bird/turbine interactions, especially in certain families that rely heavily on wind currents for movements, such as raptors. This report addresses these issues by comparing and contrasting available information from studies across the globe. First the identified effects associated with windfarms will be addressed based on the evidence of impacts from case studies. Next, the most commonly used mitigation and monitoring techniques will be examined. Then, other considerations, including offshore versus onshore windfarms and their differences in impacts and problems, will then be discussed. Finally, a short summary of other suggested, but as yet untried, techniques will be reviewed.

II. IDENTIFIED EFFECTS OF WINDFARMS ON BIRDS

The most widely discussed problem associated with windfarms is the fatal collisions that occur between birds and wind turbines. Collisions with turbines remain the largest potential direct threat to birds from any wind farm and evidence from extensive work at onshore sites has demonstrated that collisions will occur no matter where a farm is located (Tingley 2003). Other forms of mortality as well as indirect effects, such as habitat loss and disturbance, are also common problems but ones that tend to have far less coverage. This appears to be mostly attributed to other problems having less of a direct impact, meaning they do not cause immediate fatalities or the number of fatalities is low.

I will first outline each of the identified effects, and then provide a final synopsis of the relative impacts of these various direct and indirect effects. This will attempt to assess the severity of the effect if known and identify which effects require further research to accurately gauge.

1. Fatal and non-fatal collisions.

Carcass searches have shown that collisions with wind turbines cause bird fatalities (BirdLife International 2003, Erickson et al 2001, NWCC 2002, Hebert & Reese 1995, Percival 2003, Rugge et al 2003, Smallwood & Thelander 2004, Thomas 1999, Tingley 2003). All species of birds are at risk of colliding with wind turbines. Some studies have shown however, that in certain habitats specific groups of birds (raptors, soaring birds, wading birds around nearshore farms, and waterfowl around offshore farms) are more at risk than others (Becker et al 1999, Rugge et al 2003). The placement and operation of wind turbines can make birds vulnerable to turbine collisions, especially in cases where birds may be predisposed to sensitivity to turbines due to relative abundance, behaviours, and ecological relationships (Rugge et al 2003). Threatened and endangered bird populations, although no more susceptible than any other bird species, are especially impacted by collisions because of already low population numbers. The loss of only a few breeding adults can be detrimental to an already vulnerable population.

Making projections of the potential magnitude of wind turbine-related avian fatalities is problematic because of the frequent lack of objective information (BirdLife International 2003). The weight of evidence to date indicates that locations with high bird use, especially by species of conservation concern, are not suitable for wind farm development (BirdLife International 2003). Taking into account all of the impacts windfarms may cause to bird populations, collisions with wind turbines represent the largest direct risk to bird life, yet the severity of this risk may in actuality not be high (Kingsley & Whittam 2001). The other problems that are typically associated with windfarms, although not unimportant, rarely result in the direct loss of a bird's life.

2. Fatalities from electrocution and line collisions.

Perching on and, in some cases, collision with electrical lines has been found to be a cause of bird fatalities at windfarm sites (NWCC 2002, Hebert & Reese 1995). The U.S. Fish and Wildlife Service reports tens of thousands of avian fatalities per year due to collisions with power transmission and distribution lines… (Erickson et al 2001). Based on the limited studies, waterfowl including ducks, geese, swans, and cranes appear to be most susceptible to powerline collisions when powerlines are located near wetlands. In upland habitats away from wetlands, raptors and passerines appear most susceptible to collision (Erickson et al 2001).

Perching birds, particularly passerines and raptors, have been shown to be more at risk of electrocution than most other bird groups. Raptors are susceptible to electrocution because of their tendency to use perches during hunting and daylight movement. For most passerines it is their sheer weight of numbers, coupled with their perching tendencies, which make them more disproportionately affected than other birds. Potentially, other groups may be affected in areas where they are more common, such as marine birds around nearshore and offshore wind farm sites.

While deaths from electrocution do happen, the overall number of fatalities is low when compared to other types of collision mortalities. The results from a study done at the Altamont Pass WRA showed that approximately 0.8% of fatalities were from electrocution and 0.2% from wire strikes (Smallwood & Thelander 2004). Although these numbers are small, at large windfarms, electrocution and wire strike fatalities may become problematic.

3. Habitat disturbance due to noise and constant turbine motion.

Because of the constant noise and motion associated with wind turbines, studies have shown that birds are less likely to populate the area surrounding a windfarm or wind turbine (BirdLife International 2003, Kingsley & Whittam 2001, Percival 2003, Rugge et al 2003, Thomas 1999, Tingley 2003). The noise and activity of operations have the potential to disturb local breeding and/or foraging birds, causing a decrease in nesting success and physical health and contributing to increased mortality (Kingsley & Whittam 2001). Noise disturbance can be compounded by visual disturbance, from either the presence of the wind turbines or the large, rotational movements of the blades (Tingley 2003). In addition, increased human activity in the vicinity of the turbines (e.g. for maintenance) can further cause birds to avoid the area (Tingley 2003).

Habitat losses due to avoiding disturbance are labelled "indirect," - as compared to "direct" - habitat losses; the wind farms are not physically excluding birds from the habitat, but they may make the habitat less desirable for settling birds. This could make areas in which windfarms are located produce sink populations, or at least be perceived by the birds as poor habitat and be differentially settled by lower-quality individuals. Indirect habitat losses will mostly affect local species relying on specific areas for resources, but it could potentially impact migratory populations that use a specific area as a staging ground (Tingley 2003).

4. Habitat loss from the development of the area for the windfarm site.

Problems with potential loss of habitat occur when the proposed site of a windfarm is being actively occupied by bird life (BirdLife International 2003, Percival 2003, Rugge et al 2003, Smallwood & Thelander 2004, Thomas 1999, Tingley 2003). Such habitat loss, effectively displacing birds from areas in which the windfarms are built, is the other main impact of wind farms on birds along with collisions (Percival 2003). Habitat disturbance affects certain bird species more than others. Generally there is little evidence of any major disturbance impacts in upland habitats on waders, grouse or passerines, although the loss of habitat sensitive species with loss of specific habitat types (such as woodlands) will be likely. There is generally more evidence of displacement of birds around wind farms occurring in coastal habitats. Most of the examples of such disturbance relate to waterfowl, where the birds were displaced over distances of up to 800m (wintering birds) and 300m (breeding birds) (Percival 2003).

There are several reliable studies indicating negative effects up to 600m from wind turbines (BirdLife International 2003). In a large wind farm, even this relatively small exclusion area around an individual turbine, may amount to a cumulatively significant exclusion area, or area of reduced use, even within a single wind farm (BirdLife International 2003).

Although almost all bird species can be affected by habitat loss due to windfarm installation, the low level of impact that is commonly associated with habitat loss in this manner is usually deemed acceptable in relation to the power generation potential of the farms. This is particularly the case if the footprint of the wind farm will result in the loss of only small proportion of the total available land base of a particular habitat, or unless the bird population being affected is an endangered or likewise at risk group.

5. Older model turbine towers provide dangerous perching sites.

Older model turbine towers, ones constructed of a lattice framework instead of a tubular pole, have been shown to increase the rate of turbine collisions among certain bird groups (Barrios et al 2004). Raptors are especially at risk because they seem to show an affinity for using these old towers as perching sites (Smallwood & Thelander 2004).

Perching is both a direct and indirect risk to birds like raptors that use lattice type towers as perch sites (Curry & Kerlinger 2002). The direct risk is through collision while attempting to perch or take off from a turbine that is operating. The indirect risk is likely to be through habituation. Turbines that permit perching allow birds to spend time in very close proximity to turbines, thereby promoting habituation. They are then more likely to approach operating turbines and collide with rotors (Curry & Kerlinger 2002).

As older model wind turbines are decommissioned or upgraded, this issue will eventually become less of a problem.

SYNOPSIS

The problems that have been identified above are the most common issues to be found regarding the impact of windfarms on birds. None of these problems however, are common at all windfarms. Some WRA's have none of these problems while others have more. The degree of impact caused by a windfarm is a result of its size and the area in which it is situated. Both of these factors govern whether the amount of fatalities from collisions will be high or almost nonexistent. Wind turbine collisions have caused the most problems with direct fatalities in the past and will likely continue to do so in the future. However, the non-fatal impacts associated with habitat disturbance and noise/vibration pollution are not well studied or even understood. Future work should consider this as a serious concern that needs to be addressed to determine the extent and actual impact this is having on bird populations.

III. Mitigation and Monitoring Techniques

As the wind industry continues to grow better mitigation and monitoring are becoming more essential. The magnitude and severity of all impacts, not just collisions, could best be minimized by the careful siting of proposed wind farms, although there are several other effective ways to mitigate impacts through design and planning (Tingley 2003). These techniques are very important factors in the successful operation of a windfarm. Most of the advances in mitigation have been a result of lengthy and diligent monitoring. As with any type of improvement the initial research must be done and follow up studies are critical.

1. Mitigation

A more comprehensive method for site selection is needed (Baden et al 2004, Bay et al 2003, BirdLife International 2003, Handbook 2002, Tingley 2003). Based on information to date, siting of windplants appears to be the most significant factor related to bird mortality (Erickson et al, 2001). In the past, inadequate research of a site for a windfarm has caused many problems when the farm becomes operational. Areas that are intersected by natural flyways are typically not suitable for windfarms. 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 (Rugge et al 2003). Migration stopover locations and migration corridors are generally situated near large bodies of water, along river corridors, and, to a lesser extent, along ridgelines (Kerlinger 2003). These areas should be carefully analysed before being considered for windfarm development. Placement of wind farms in suitable industrial areas, harbour complexes and on agricultural land should be considered in addition to more traditional upland and coastal sites (BirdLife International 2003).

Older model turbine towers need to be updated (Barrios et al 2004). Updating older model turbines towers from a lattice framework to a tubular construction has proven to be very effective in reducing collisions. Stringing mesh wire around lattice towers has also helped to reduce collisions (Smallwood & Thelander 2004). Both of these mitigation techniques can be widely used and at any WRA.

Burying or insulating lines reduces the risk of electrocution fatalities (Kerlinger 2003). In areas where this has be done, instances of electrocution have all but disappeared. This technique can only be used when the ground type permits. Areas that are extremely rocky or with little to no ground soil usually prevent burying of lines.

Stopping turbines during peak migration movement reduces high collision rates (Richardson 1998). Stopping turbines has been shown to be very successful in reducing mass collisions during migration. This technique can be instituted at any windfarm and does not necessitate the shutting down of the all turbines. Commonly, only the turbines that are directly in the migration path need to be stopped. To utilize this type of mitigation, a detailed understanding of the migration patterns of the bird species in the area is necessary.

Attaching lighting to wind turbines can be used to alert birds but has to be done with extreme caution. Offshore wind turbines, if lit at night, could potentially pose similar risk to communication towers (Percival 2001). Artificial lights at night have been well documented as being an attractant to migrant birds. Birds migrating at night can be attracted to sources of artificial light, particularly during periods of inclement weather (Percival 2001). Lighting appears to be the single most critical attractant, and preliminary research indicates that solid and pulsating red lights seem to be more attractive to birds at night during inclement weather conditions than are white strobe lights (Erickson et al 2001).

2. Monitoring

Carcass searches are helpful but have limited efficiency (Dieter et al 2000, Rugge et al 2003, Smallwood & Thelander 2004). Factors such as vegetation type, scavenger density, carcass size, and terrain all influence the outcome of a carcass search. Eagles and other large carcasses remain detectable for months or longer (Curry & Kerlinger 2002). It is likely that the reported numbers of fatalities of large birds are close to the actual numbers killed, whereas the reported numbers of smaller birds are less representative (Curry & Kerlinger 2002). Carcass searches can give an estimate of collision fatalities but are only useful in particular areas. Locations with low to zero scavenger density and little to no ground vegetation are the best sites.

Visual searches and cameras help to determine bird proximity to windfarms (Cooper 1995). Studying the movements of local and migratory populations helps to establish when or if turbines need to be shut down. Knowing where and when birds are moving is the best way to prevent bird turbine collisions. This technique is especially useful for areas that experience daily mass bird movement such as offshore and nearshore windfarms.

Breeding bird surveys determine the species of birds native to the area (Kerlinger 2003). Knowing exactly what species of birds are in the area adjacent to a windfarm helps to determine the measures that need to be taken to prevent fatalities. A breeding bird survey should ideally be done during the site selection process. This is the best time to identify whether there are threatened or endangered birds breeding in the area.

SYNOPSIS

Certain types of mitigation and monitoring techniques work better than others. Using a more comprehensive method for site selection is one of the best mitigation techniques. Better site selection would eliminate many of the problems that are common at windfarms. However, any mitigation techniques that are used will be helpful as long as they have been properly researched. The same applies to monitoring, although dependency on one technique will never provide useful data. This trend seems to be prevalent with carcass searches. It is a useful technique but should never be solely relied upon to give an accurate estimate of the WRA’s avian fatalities. Pre-site monitoring is crucial before actual site construction starts. Establishing population estimates, movement patterns, site use, and the details of seasonal variations enables better assessment of the impacts after the windfarm has been constructed. While neighbouring control sites are useful, accurate data can only be gathered at the same site of the proposed windfarm. To account for seasonal variations in population and movement, it is recommended that pre-site monitoring take place for two to three years prior to construction to enable gathering of accurate data.

IV. Other Considerations – Offshore vs. Onshore

The issues and challenges surrounding a windfarm are not consistent among all WRA's. There is a great difference in the problems faced at offshore and onshore sites. Many of the challenges offshore sites face are non-existent at onshore sites and vice versa. Weather patterns and a greater frequency of flock movement are just a few of the unique concerns dealt with at offshore and nearshore windfarms.

Weather patterns affect collision rates at offshore sites differently by affecting flight behaviour (Curry & Kerlinger 2002, Dirksen et al 1999, Kingsley & Whittam 2001, Percival 2001, Tingley 2003). During calm weather, massive movements over large distances took place at dawn, resulting in large congregations of birds (Dirksen et al 1999). Mist and strong winds reduced the intensity of these morning flights (Dirksen et al 1999). Collision risk with wind turbines is likely to be highest when migrants (particularly nocturnal ones) meet unfavourable conditions (head winds and rain) during their journey (Percival 2001). Fog is a difficult weather factor to deal with as it conceals the turbines and towers. On foggy days, the probability of a collision increases (Kingsley & Whittam 2001). Storms and squalls can also hinder birds by pushing them into the area of a windfarm when visibility is low.

Flock movement is harder to contend with at offshore sites (Curry & Kerlinger 2002, Dirksen et al 1999, Percival 2001). On the coast, compared to inland, a higher proportion of bird species exhibit either colonial or flocking tendencies. Daily mass movements have the potential to result in high collision rates. On days of normal visibility the chance of this happening is quite small however. Only when visibility is hindered, such as in the evening or in heavy fog, does a flock become in danger of collision.

Birds around offshore sites can exhibit higher rates of nocturnal movement (Dirksen et al 1999). At night and at dusk, flight activity in the direct vicinity of the windfarm is lower than further away from it. This effect is noticeable up to a distance of 1000-1500 m from the turbines and is stronger closer to the turbines. The effect is strongest in moonlit nights and relatively small at dusk. At dawn, no effect of the windfarm on flight movements was noticeable (Dirksen et al 1999). Like fog, darkness greatly reduces visibility and can cause an increase in collisions. Striping turbine blades or adding lights to improve reaction time has met with mixed success. The use of solid red or pulsating red warning lights should be avoided, as research has shown that these lights disrupt night-migrating birds (causing curved, circling or hovering behaviour) at a much higher rate than white strobe lights (Kingsley & Whittam 2001).

Site selection for offshore sites is different than that of onshore sites (BirdLife International 2003, Kerlinger 2001, Percival 2001, Tingley 2003). Because of inclement weather, a tendency to flock, and nocturnal habits, selecting a site for an offshore or nearshore windfarm is a very delicate process. The site selection process needs to be very thorough and not rushed. Like onshore sites, pre-site monitoring should be in place for a minimum of two years before construction of the windfarm.

Synopsis

Windfarms that are on or near the water have an entirely different set of issues to deal with than windfarms that are farther inland. Two of the biggest issues when dealing with offshore or nearshore windfarms is the high rates of daily mass movement and increased rates of nocturnal movement. Identification of flocking patterns, both daily and seasonal, in relation to individual species is necessary before and after site construction. This will enable better monitoring and prevention techniques. Future research needs to be done to better understand the extent of the impacts and the overall semantics of how the operation of an offshore windfarm differs from an onshore windfarm.

V. UNTRIED TECHNIQUES

As older techniques become outdated, new methods for dealing with problems associated with birds and windfarms arise. As newer techniques appear the mitigation and monitoring called for becomes more rigorous.

Better assessment methodology is needed. A more stringent type of methodology used to evaluate a windfarm before, during and after its construction is something that would greatly reduce the common problems that are being seen in WRA's. Environmental Impact Assessment [EIA] is now an important part of the application process for wind farms in Ireland (and indeed across Europe), and ornithology ornithological assessment is usually an integral part of that process (Percival 2003). The key aims of the methodology are to establish a process by which developers and conservation agencies can work together to ensure that wind farm development does not occur in inappropriate locations where important bird populations may be affected, to ensure that bird issues do not hinder development of wind farms at sites where they are not significant, and to identify where appropriate mitigation measures should be undertaken and where developments may be able to deliver a conservation gain to the area's ornithological interest (Percival 2003). Enhanced assessment methodology would ensure that the serious problems that need to be dealt with would be and that the issues that have been overly glorified would be handled accordingly.

Radar and acoustic monitoring are useful techniques for tracking bird movement (Belle et al 2000, Cooper 1995, Evans 2003). Radar and acoustic techniques are two different means for monitoring nocturnal bird migration, each with its own strengths and weaknesses (Evans 2003). Radar is the only way to monitor every target flying but gives little species information. Acoustic methods give species information but do not provide information on birds that don't call. The best coverage for wind turbine studies would use both techniques (Evans 2003). Determining typical flock patterns and migration routes helps to determine suitable locations for windfarms that can in turn lower the quantity of collision fatalities. Also, knowing the location and movement of bird flocks helps to prevent collisions by ensuring that the appropriate steps can be taken in time to redirect flock movement. Turbines can also be turned off in necessary to accommodate large bird movements.

Reducing rodent populations in areas with high raptor abundance diminishes the risk of collision fatalities (Smallwood & Thelander 2004). 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) (Rugge et al 2003). In the Altamont Pass WRA, it was found that the high density of rodents was attracting raptors and thereby increasing the chance of a collision. Reducing cover and vegetation helps to ensure that birds will not be attracted unduly to an area, whether to nest or to hunt.

SYNOPSIS

New techniques for mitigation and monitoring are past due and sorely needed if the wind industry is to ever earn a clear reputation. While many of the methods call for firmer guidelines, accepting them now will facilitate improved and more trouble-free operation in the future.

APPENDIX I. A SUMMARY OF LITERATURE PERTAINING TO BIRD/WINDFARM INTERACTIONS.

1. **Baden, S.A. and James, M.A. 2004. Wind Energy Development and Avian Effects in Northern Arizona: A review of the state of current knowledge and recommendations for minimizing impacts. Arizona: Grand Canyon Trust.**

   Pages: Sixty-nine (69).
   Recommendations for site selection using GIS and pre-setup studies to determine high use areas and bird abundance. Details on wind turbine specifications and their primary affects on birds.

2. **Barrios, L. and Rodríguez, A. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology 41: 72–81.**

   Pages: Ten (10).
   Bird mortality was heaviest primarily during certain seasons by mostly resident populations of a select few species. Migration mortality was low. Lattice towers are more dangerous than tubular towers due to availability as perching sites. Age does not seem to play a great part in bird mortality.

3. **Bay, K., Erickson, W.P., Good, R.E., Jeffery, J., Johnson, G.D., Sawyer, H., and Young Jr., D.P. 2003. Wildlife Baseline Study for the Wild Horse Wind Project. Portland, Oregon: Zilkha Renewable Energy.**

   Pages: Eighty-two (82).
   A report outlining the fundamentals and results of a study designed to determine if an area is suitable for installation of wind turbines. Results include statistics on avian density and diversity as well as seasonal abundance. Average flight heights by avian grouping are mentioned in relation to the occurrence of possible collisions.

4. **Becker, P.S., Erickson, W.P., Johnson, G.D., Kronner, K., and Strickland, M.D. (Western EcoSystems Technology, Inc.) and Orloff, S. (IBIS Environmental Services). 1999. NREL/SR-500-26902. Baseline Avian Use and Behaviour at the CARES Wind Plant Site, Klickitat County, Washington. Final Report. Golden, Colorado: National Renewable Energy Laboratory.**

   Pages: Seventy-five (75).
   Bird use was analyzed and data was collected on abundance, flight heights, seasonal usage and potential turbine exposure. The main groups of interest were raptors and other large birds. Red-tailed hawks and Golden Eagles were found to have the highest risk of potential turbine exposure while the passerines with the highest risk were the Common Raven, American Robin and Horned Lark.

5. **Van Belle, J., Buurma L.S., Maan, M., and van Gasteren, H. 2000. Using radar to obtain a quantitative description of summer bird movements in the Dutch coastal area. The Netherlands: International Bird Strike Committee.**

   Pages: Fifteen (15).
   Radar was used to track the movements of coastal birds during the summer. Data showed that there was not significant difference between day and night movements. As well, it was found that the majority (75%) of birds flew below 50 meters.

6. **Report by BirdLife International. 2003. Wind farms and Birds: An analysis of the effects of wind farms on birds and guidance on environmental assessment criteria and site selection issues. Stasbourg: RSPB/BirdLife.**

   Pages: Fifty-eight (58).
   Based on reviewed literature this report covers issues such as disturbance, collision mortality and habitat alteration. Guidance is also given on the criteria for assessing environmental impacts of windfarms on birds and precautions for site selection. Both onshore and offshore factors are discussed.

7. **Cooper, B.A., Stickney, T.J, and Mabee, T.J. 2003. A Radar Study of Nocturnal Bird Migration at the Proposed Chautauqua Wind Energy Facility, New York. Forest Grove, Oregon: ABR, INC.**

   Pages: Thirty-two (32).
   A radar study of the nocturnal movements of bird migration at a proposed wind farm. Radar techniques were used to collect information on flight direction, migration intensity (passage rates), and the flight altitude of nocturnal passerine migrants. Nocturnal passage rates and mean flight altitudes were found to be highly variable during the study time.

8. **Cooper, B.A. 1995. National Avian -Wind Power Planning Meeting Proceedings. Use of Radar for Wind Power - Related Avian Research. ABR, INC.**

   Pages: Fifteen (15).
   The practical aspects of using radar for wind power-related avian studies were discussed based on benefits and limitations. A brief history of radar was given along with some of the benefits and limitations of some of the most commonly used types of radars. Ideas on how radar could be used for avian research before and after windfarm development are discussed.

9. **Curry, R. and Kerlinger, P. 2002. Desktop Avian Risk Assessment for the Long Island Power Authority Offshore Wind Energy Project. AWS Scientific, Inc. and Long Island Power Authority. Cape May Point, New Jersey: Curry & Kerlinger, L.L.C.**

   Pages: Sixty-two (62).
   This paper discusses the different types of impacts that are encountered with offshore wind turbines. Offshore weather effects and daily and seasonal movements are also considered. An

inventory of avian studies that have been conducted concerning wind energy is listed for the United States, Canada and Europe.

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

    Pages: Twelve (12).
    Bird mortalities due to wind turbine collision are affected by season and climatic conditions. Because of low avian density, mortality during the winter is low to nonexistent. Carcass recovery under turbines can be influenced by bird size, cover type and vegetation height. Not all birds fall directly below the respective turbine when struck.

11. **Dirksen, S., van de Haterd, R.J.W., van Horssen, P., Larsen, J.K., Schekkerman, H., Spaans, A.L., Tulp, I., and van der Winden, J. 1999. Nocturnal flight activity of sea ducks near the windfarm Tunø Knob in the Kattegat. Bureau Waardenburg bv.**

    Pages: Seventy (70).
    A study of sea ducks to determine their flight times, disturbance values and responses to the wind farm. Flight times occur during the day and night. Flight activity is largely determined by light availability. Flight activity near the windfarm was only affected at dusk and during the night. Some sea ducks were able to correct their flight and avoid the windfarm thus reducing possible collisions. A short list of recommendations is given to minimize the impact on sea ducks in and around the windfarm.

12. **Erickson, W.P., Good, R.E., Johnson, G.D., Sernka, K.J., Strickland, M.D., and Young Jr., D.P. 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 (NWCC) Resource Document.**

    Pages: Sixty-seven (67).
    Results on avian mortality due to various types of collisions including wind turbines are discussed and compared. An estimate of 0.01 to 0.02 percent is assigned to the number of collision deaths due to wind turbines out of the total number of yearly collision deaths. Many of the collision study results did not take into account scavenging or searcher efficiency.

13. **Evans, W.R. 2003. Applications of Acoustic Bird Monitoring for the Wind Power Industry. Ithaca, New York: National Avian - Wind Power Planning Meeting III.**

    Pages: Twelve (12).
    The process of acoustic monitoring was used to track nocturnal bird movement. Three different applications were examined. Night migration near existing tall structures, documenting broad front density gradients by species at night, and localization of calling night migrants.

14. **Hebert, E. and Reese, E. 1995. Avian Collision and Electrocution: An Annotated Bibliography. California Energy Commission. Publication Number: P700-95-001.**

    Pages: One hundred and fifteen (115).
    A large collection of literature dealing with all possible sources of avian mortality in relation to collision and electrocution.

15. **Kerlinger, P. 2003. Avian Risk Assessment for the East Haven windfarm, East Mountain Demonstration Project Essex County, Vermont. Cape May Point: Curry & Kerlinger, L.L.C.**

    Pages: Forty-seven (47).
    A report detailing the findings of a risk assessment for the East Haven windfarm. The potential for avian and bat collisions was found to be minimal. Recommendations included burying the electrical lines running between turbines, limiting use of lights, allowing natural forestation around turbines and a breeding bird study to determine if listed species occupy the area.

16. **Kerlinger, P. 2001. Avian Issues and Potential Impacts Associated With Wind Power Development in the Nearshore Waters of Long Island, New York. Cape May Point, Oregon: Curry & Kerlinger, L.L.C.**

    Pages: Twenty (20).
    This article discusses the issues, both legal and ecological, associated with wind power in relation to nearshore and offshore sites. Avian mortality and disturbance are topics incorporated within ecological issues. General findings on topography, turbines, lights, wires and other structural aspects are also covered. “Birds in a vast majority of instances simply fly around wind turbines without being impacted”.

17. **Kingsley, A. and Whittam, B. 2001. Potential Impacts of Wind Turbines on Birds at North Cape, Prince Edward Island. Sackville, New Brunswick: Bird Studies Canada.**

    Pages: Thirty-three (33).
    A summary of avian mortality broken down into further causes, disturbance and the effect of fog on mortality. A section on the potential impacts of wind turbines on birds is included and details mainly the possibility for collision and disturbance. Monitoring and methods for reducing mortality are discussed.

18. **National Avian-Wind Power Planning Meeting Proceedings. 1994. Avian Mortality at Wind Plants: Past and Ongoing Research.**

    Pages: Fifteen (15).
    A study comprised of six different presentations dealing with avian mortality at wind plants. Topics covered deal primarily with research done on avian mortality and bird/wind turbine interactions.

19. **National Wind Coordinating Committee. Permitting of Wind Energy Facilities. Revised 2002. Prepared by the NWCC Siting Subcommittee.**

Pages: Fifty-eight (58).
A report detailing the processes and procedures related to the setup and development of windfarms. A section dealing with avian fatalities including collision and electrocution resulting from windfarms is included.

20. **Percival, S.M. 2003. Birds and wind farms in Ireland: A review of potential Issues and Impact Assessment. Durham, UK: Ecology Consulting.**

Pages: Twenty-five (25).
A summary of the collision and disturbance rates of birds and wind turbines from various countries is presented and discussed. An assessment methodology designed to ensure better avian/windfarm interactions is mentioned in detail.

21. **Percival, S.M. 2001. Assessment of the Effects of Offshore Wind Farms on Birds. ETSU W/13/00565/REP. Durham, UK: Ecology Consulting.**

Pages: Ninety-six (96).
A detailed report discussing the various effects of offshore windfarms on birds including information from several other offshore studies. Large appendices list data on potentially vulnerable areas for seabirds in relation to windfarms, issues affecting the development of offshore windfarms and important estuarine bird and seabird sites in the UK.

22. **Richardson, W.J. 1998. Bird Migration and Wind Turbines: Migration Timing, Flight Behaviour, and Collision Risk. LGL Ltd.**

Pages: Eight (08).
Seasonal timing, hourly timing, weather effects on number aloft, altitudes, topographic features and favoured stopover habitat are topics discussed in relation to interactions with windfarms and turbines.

23. **Rugge, L., Smallwood, K.S. and Thelander, C.G. 2003. NREL/SR-500-33829. Bird Risk Behaviours and Fatalities at the Altamont Pass Wind Resource Area. Ojai, California: BioResource Consultants.**

Pages: Ninety-two (92).
A report discussing the various issues and topics associated with avian interactions at the Altamont Pass WRA. Topics include seasonal usage patterns, fatality searches, bird use, bird behaviour and the presence of burrowing rodents in relation to raptor prey. The Altamont Pass WRA causes large numbers of raptor fatalities in comparison with other windfarms. "…one may estimate that as many as 1,026 birds are killed per year in the APWRA. Of these, approximately 50% are expected to be raptors. To date, golden eagles represent 2.4%

of the total bird fatalities in our study. This percentage yields an estimated 24 golden eagle deaths per year in the APWRA."

24. Smallwood, K.S. and Thelander, C.G. 2004. Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area. Final Report. PIER-EA Contract No. 500-01-019. Ojai, California: BioResource Consultants.

Pages: Five hundred and twenty (520).
This report is broken down into seven chapters that deal with the problem of bird mortality, cause of death and locations of bird carcasses, fatality search methods, impacts to birds, range management, distribution and abundance of fossorial animal burrows and bird fatality associations. Recommendations are included to reduce avian collisions as well as to reduce the abundance of avifauna in the area.

25. Thomas, R. 1999. An Assessment of the Impact of Wind Turbines on Birds at Ten Windfarm Sites in the UK. University College London, UK: Sustainable Development International.

Pages: Six (06).
A summary of the impacts of wind turbines on bird life taken from ten windfarms. Data was compared against control sites in similar habitats. The densities of birds at the control sites were higher than at the windfarm sites. "Taller wind turbines, longer rotor blade length, and larger windfarms are associated with lower bird densities".

26. Tingley, M.W. 2003. Effects of Offshore Wind Farms on Birds: "Cuisinarts of the Sky" or Just Tilting At Windmills? (Bachelors thesis, Harvard University).

Pages: One hundred and twenty-two (122).
The potential effects of offshore wind turbines on birds are discussed including collisions, disturbance and habitat loss and alteration. Scientific evidence for offshore wind farm effects and the planning and design of offshore wind farms is examined. Foreseeing problems before a windfarm is built and then monitoring afterwards was found to be extremely important.