BIRDS, BATS AND COASTAL WIND FARM DEVELOPMENT IN MAINE: A LITERATURE REVIEW

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BIRDS, BATS AND COASTAL WIND FARM DEVELOPMENT IN MAINE: A LITERATURE REVIEW

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1. Executive Summary

Producing energy of any type has impacts on local, regional, and global bird and bat populations. Globally, the impact of wind energy on wildlife is likely less than cradle-to-grave impacts of fossil fuels and nuclear power. Annual avian fatalities from wind power are also likely significantly less than the combined impacts of all other anthropogenic sources such as global warming, contaminants, habitat loss, buildings, cats, and cars.

While wind energy may partially mitigate the effects fossil fuels have on global warming, it does introduce a new stressor to specific bird and bat populations. Many of the potential impacts of wind farms, however, can be significantly reduced through proper siting and mitigation measures. This paper reviews many of the scientific studies that are ongoing in Europe as well as recommendations proposed by researchers to minimize potential effects.

Throughout the scientific literature there are three consistent conclusions: 1) proper siting of wind farms can significantly reduce avian impacts; 2) pre-construction baseline survey work is critical to ensure proper siting; and 3) there is great site, species, season, and weather variation. These observations are particularly germane to Maine, which supports regionally significant bird and bat populations, and where Governor Baldacci's Ocean Energy Task Force (OETF) is saddled with the challenge to identify five test sites for offshore wind turbines by December 15th, 2009.

This large-scale planning effort that Maine is undertaking to identify these sites is similar to the Strategic Environmental Assessments (SEAs) established in Europe. The research in Europe has found that the primary impacts of wind farms—habitat loss and collision mortality—can significantly be reduced by avoiding critical habitats, such as seabird nesting areas, and sensitive raptor habitat such as eagle nests. Fortunately for the Maine process, these critical habitats are currently mapped and easily avoided.

While the best site planning will reduce mortality and habitat loss, there will invariably be impacts on birds and bats. To best assess the direct impacts, European researchers recommend specific monitoring technology and protocols that may be applicable to Maine. Additionally, the papers recommend potential adaptive management techniques such as turning off turbines when radar detects migrating birds and bats, and other mitigation measures.

Finally, because of the complexity of these issues, and the necessity to make decisions based on existing data that in many cases is limited, we recommend the formation of a Bird and Bat Advisory Board that can assist Maine law makers with the difficult decisions on where to site both test and large-scale commercial facilities. This board would be composed of state, federal, and NGO scientists and would also provide insight into pre- and post-construction monitoring to ensure that Maine efforts are congruent not only with other efforts in New England, but also with those in Europe.

2. Introduction

To aid the Maine Ocean Energy Task Force (OETF) in selecting test sites for offshore wind turbines and the development of a permitting process, BioDiversity Research Institute has conducted a review of scientific literature relating the impact of wind turbines on birds and bats. We conducted the work unsolicited and independent from the OETF and other NGO's or state or federal agencies.

The following literature review summarizes the areas of potential impacts, monitoring methodologies, adaptive management options, and types of mitigation while providing some Maine-specific recommendations. This review is primarily focused on the literature of marine wind farm impacts in Europe, although there are some references to terrestrial studies that may apply to offshore development.

2.1 Current coastal and offshore wind energy efforts in Maine

The Governor's 2007 task force on wind power identified the coast of Maine as having "outstanding" wind power potential, and recommended that Maine should "aggressively pursue development of Maine's offshore wind potential" (Report of the Governor's Task Force on Wind Power Development 2008).

In a November executive order, Governor Baldacci established the Ocean Energy Task Force (OETF) to recommend strategies to install at least 300 megawatts of wind capacity in Maine coastal waters (Maine State Planning Office website). The OETF has developed a bill currently being considered by the Maine legislature to identify five test sites for offshore wind turbines by December 15, 2009.

2.2 Impacts of wind compared to other energy sources

Only recently have researchers attempted to quantify how different energy resources impact bird populations. Although the area requires significantly more research, Sovacool (2009) quantified the potential number of birds killed by gigawatt-hour (GWh) for energy produced from wind farms, nuclear power, and fossil fuel. The study, as described by the author, used “rudimentary” numbers and is intended to provoke further research.

The study found that wind farms were responsible for 0.3 fatalities per GWh, nuclear 0.4, and fossil fuel power stations 5.2. By this estimate annually in the United States, 7,000 birds were killed by wind farms, 327,000 by nuclear plants, and 14.5 million by fossil-fueled power plants. From these calculations the author concludes that producing energy from fossil fuels has significantly greater impact to birds and bats than wind and nuclear power (Sovacool 2009).

However, it is important to note that Sovacool’s estimate of bird fatalities from wind farms is imprecise: 7,000 birds killed by wind turbines could be a gross underestimate. For example, Smallwood and Thelander (2008) estimate that as many as 11,520 birds could be killed annually at Altamont Pass Wind Resource Area, California, and Erickson et. al. (2005) estimates that up to 37,000 birds are killed in the U.S. each year by wind turbines.

2.3 Impacts of wind farms compared to other anthropogenic sources

Often the potential impact of wind farms on birds are put within the context of impacts of other anthropogenic activities on birds (e.g. cars, cats, buildings), which Erickson et al. (2005) estimate kill 500 million to over 1 billion birds annually. The National Academy of Science, however, stresses the danger in making this comparison because the data used to make these estimates are poor; human-caused fatalities affect species differently; and aggregating fatalities across the entire U.S. does not account for region-specific demographic effects; e.g. 10,000 starlings killed in New York is very different than 10,000 eagles killed in California (NAS 2007). The potential impact of offshore wind farms on birds should be considered as an additional stressor on bird populations. This additional stressor to existing impacts has the potential to place certain bird populations such as peregrine falcons at a greater risk.

2.4 The importance of the coast of Maine to birds

The coast of Maine provides a unique habitat for many birds during wintering, migration, and breeding. For some species the Maine coast is central to the survival of their North American population. A few examples:

- Seabirds—Maine hosts many species of breeding seabirds including ~7,500 pairs of common terns, 4,300 pairs of Arctic terns, 200 pairs of the endangered roseate terns, and 920 pairs of Atlantic puffins (Gulf of Maine Seabird Working Group).

- Purple sandpipers—Two-thirds of the North American population winters in Maine, mostly within Penobscot Bay (7,000 to 10,000 birds) (L. Tudor, Maine Department of Inland Fisheries and Wildlife, pers. com.).

- Harlequin ducks—Over 70% of the Eastern North American population winters in Maine (~1,300 of 1,800 individuals) and ~900 birds are in outer Penobscot Bay (L. Tudor, Maine Department of Inland Fisheries and Wildlife, pers. com.).

- Eagle nests—Approximately 40% of Maine's eagle nests are along the coast (BioDiversity Research Institute calculation).

- Shorebirds—The Gulf of Maine is the most important southern migration staging area of the East Coast for shorebirds (L. Tudor, Maine Department of Inland Fisheries and Wildlife, pers. com.).

3. Island versus Offshore Development

Although the focus of the OETF is on offshore development, there is currently discussions about and proposed wind turbines on Maine islands from Casco Bay to Mount Desert Island, including Swan's Island, Monhegan, Vinalhaven, and several Casco Bay islands. These small wind projects, one to three turbines, currently fall within the expedited permitting process for wind development developed during the first wind task force.

The Maine islands provide unique habitat to breeding, migratory, and winter birds. In particular these islands are regionally significant for the survival of many species that utilize parts of the coast in distinctly different manners. Although an exhaustive discussion of the Maine islands is out of the scope of this paper, the islands are a natural resource significantly different from inland areas where the expedited permitting process also applies. We would strongly suggest that the Maine Department of Inland Fisheries and Wildlife and the Maine Department of Environmental Protection review the permitting process for wind development on Maine islands, and, if appropriate, recommend changes to the current legislation governing expedited permitting.

4. European Regulatory Approach

The European Union has established that all wind farm development requires environmental screening and that through Directive 2001/42/EC, governments are required to undertake a Strategic Environmental Assessment (SEA) for large-scale multi-national offshore wind-farm planning. The goal of the SEA is to determine on a large scale the most suitable areas for development that will have the least amount of impact on avian populations. The SEA requires extensive mapping of waterbird densities in order to define important breeding and feeding areas. Currently, there have been few attempts to undertake this level of large-scale planning (Fox et al. 2006).

The advantage of the SEA process is that it would aid in zoning areas of the marine environment suitable for development. This process would potentially avoid a post-selection discovery of a high concentration of a specific group of birds (Fox et al. 2006).

Additionally, through Directive 85/337/EEC (amended in Directive 97/11/EC), specific projects require an Environmental Impact Assessment (EIA). An EIA looks at site-specific impacts on individual bird populations (Fox et al. 2006).

5. TYPES OF IMPACT

Although offshore facilities avoid some of the impacts to land birds (Fox et al. 2006), they can have impacts during the breeding, migratory, and wintering seasons. These impacts are “highly dependent on species and location” (Stewart et al. 2007). There are four types of impacts that offshore wind farms can have on birds: collision, displacement due to disturbance, displacement due to the barrier effect, and direct habitat loss (Figure 1) (Drewitt and Langston 2006, Fox et al. 2006, Exo and Garthe 2003). Collectively, these impacts can have a negative impact on population size (Fox et al. 2006). There is also the potential for individual wind farms to interact to cause large cumulative impact on bird populations (Drewitt and Langston 2006). Cumulative population-level impacts must be considered, not only from other wind farms, but also from other anthropogenic sources (Fox et al. 2006).

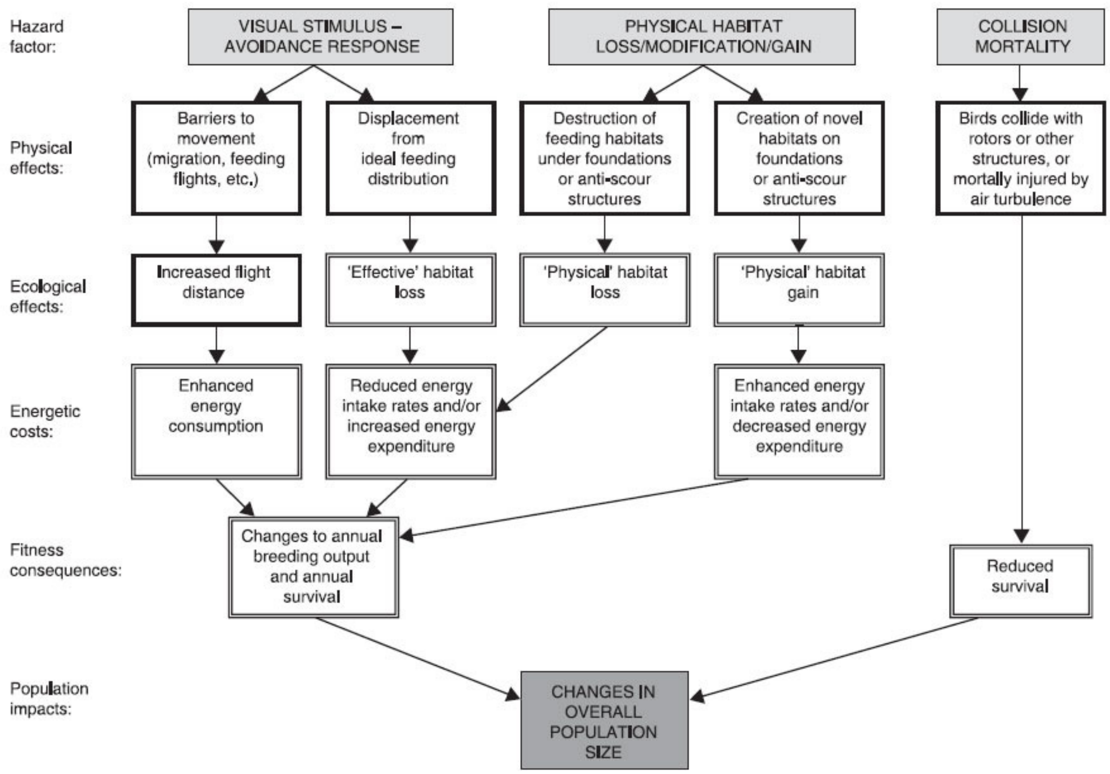

Figure 1. Flow chart describing the three major hazard factors (light shaded boxes) presented to birds by the construction of offshore wind farms, showing their physical and ecological effects on birds, the energetic costs and fitness consequences of these effects, and their ultimate impacts on the population level (dark shaded box). The boxes with a heavy solid frame indicate potentially measurable effects, the double framed boxes indicate processes that need to be modelled (see text for details).

Figure 1. From Fox et al. (2006) showing how different impacts can have population-level effects.

5.1 Displacement and avoidance

Some groups of birds, including some sea ducks, geese, and swans, avoid wind farms during migration and daily movements—this can lead to increased energy expenditure. This disturbance in their flight patterns can be caused by the presence of the turbines themselves as well as by maintenance activities. However, the waterfowl that avoid wind farms and that maybe impacted currently have healthy global population levels (Stewart et al. 2007), suggesting that at this time avoidance may not have population impacts.

The level of disturbance by a wind farm can vary widely and depends on a range of factors. These can include the season; bird species present; flock size; degree of habituation; how the birds use the area during the day; proximity to important habitats;

availability of alternate habitats; types of turbines used; and stage of life cycle (wintering, molting, breeding) (Drewitt and Langston 2006).

At an 80-turbine marine wind farm in Denmark, researchers recorded fewer loons, black scoters (*Melanitta nigra*), northern gannets (*Morus bassanus*), guillemots (*Uria aalge*), and razorbills (*Alca torda*) than expected, while gulls and terns actually showed a preference for the wind farm. In a Belgium tern colony terns did not appear to be disturbed by operating turbines (Everaert and Stienen 2006). The cause for the avoidance was not clear and may have been caused by a combination of the presence of turbines, maintenance activities, and changes in food availability (Petersen et al. 2004 *in* Drewitt and Langton 2006).

Birds can be displaced during construction and operation through the noise and vibration of the turbines, as well as through maintenance activities with boats. The degree of this impact will be related to site and species-specific factors and must be assessed on a site-by-site basis (Drewitt and Langton 2006).

5.1.1 Sea ducks

Through avoidance and consequential habitat loss, sea ducks (Anseriformes) are one of the bird taxa most vulnerable to wind farm impacts, specifically long-tailed ducks (*Clangula hyemalis*), common eider (*Somateria mollissima*), and black scoter (*Melanitta nigra*) (Stewart et al. 2007). Sea ducks will start to divert their flight path up to 3km away from a wind array during the day, and 1 km at night (synthesized by Drewitt and Langton 2006). A comparison of pre-construction and post-construction radar studies found that common eider and geese decreased in a wind farm area by a factor of 4.5 (Figure 2) (Drewitt and Langton 2006).

This behavior indicates that common eiders likely have a low probability of collision mortality. In fact, at two small nearshore turbines in Sweden only one eider collision was recorded during the migration of 1.5 million waterfowl (synthesized by Drewitt and Langton 2006). Additionally, researchers have found that only 0.9% of night migrants and 0.6% of day migrants flew close enough to the turbines to be at risk of collision (Drewitt and Langton 2006).

5.1.2 Geese

Pink-footed geese (*Anser brachyrhynchus*) avoided a terrestrial wind farm on agriculture lands in Denmark. They avoided turbines in a line by 100 meters and turbines in a cluster by 200 meters. This avoidance is similar to the 25 meter figure for barnacle geese (*Branta leucopsis*), and 400-600 meters in white-fronted geese (*Anser albifrons*) (Larsen and Madsen 2000). Researchers generally agree that 600 meters is maximum avoidance distance (Drewitt and Langton 2006).

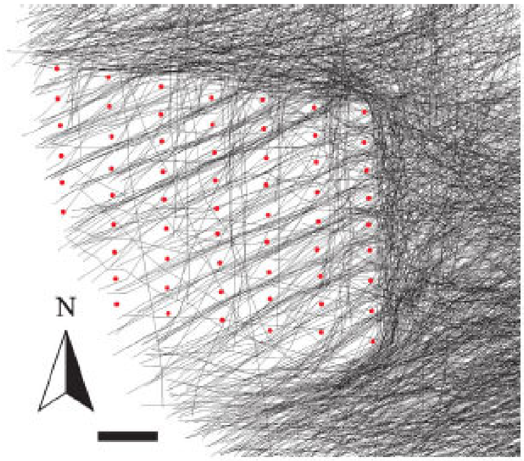

Figure 1. The westerly oriented flight trajectories during the initial operation of the wind turbines. Black lines indicate migrating waterbird flocks, red dots the wind turbines. Scale bar, 1000 m.

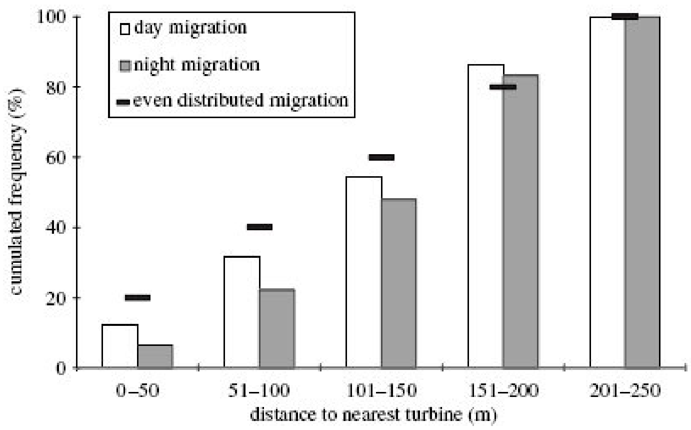

Figure 2. The cumulated frequency distribution $F_N(x)$ of the distances between bird flocks and the nearest turbine when passing the north–south oriented rows of turbines.

Figure 2. Figures taken from Desholm and Kahlert (2005) showing how eiders and geese avoid wind farms.

5.2 Barrier effect

The barrier effect is a form of displacement in which birds have to use additional energy to fly around a wind farm array. Like many factors the impact is highly variable and depends upon species, season, turbine layout, local wind patterns, and many site-specific patterns. To date research has not shown population-level impacts of the barrier effect, but there could be significant effects if a turbine array blocked the flight patterns between breeding and feeding areas. There is also the possibility of the cumulative effects of several wind farms causing birds to make extensive alterations in flight patterns leading to increased energy costs (Drewitt and Langston 2006).

Long lines of turbines can act as barriers to local and seasonal migration for non-breeding diving ducks, wigeons, cranes, and general migrants (Everaert and Stienen 2006). However, the impact can be site specific; at some sites and for some species there may not be an impact. For example, terns' and gulls' flight patterns appear not to be affected by the barrier effect, increasing the potential collision mortality impact (Everaert and Stienen 2006). Studies on breeding birds have generally found that birds are not avoiding areas around wind turbines. However, due to sustained disturbance over time there may be a reduction in local breeding populations (Drewitt and Langton 2006). Because of the uncertainty of the long-term impact of the barrier effect, further research is needed to determine whether there are reductions in local or regional populations.

5.3 Direct habitat loss

In contrast to the loss of habitat through avoidance, direct habitat loss under the turbines themselves currently appears to be minimal. Researchers estimate that only 2-5% of the entire wind farm area would be directly altered under the turbines (Fox et al. 2006). However, the effects could be greater if the underwater structure changed hydrological patterns and geomorphological processes leading to erosion. Additionally, the vibrations of the turbines could influence fish distributions and consequently food availability for piscivorous birds (Drewitt and Langton 2006). Another factor to be considered is the potential habitat loss in terrestrial habitats where transformers are placed (Drewitt and Langston 2006).

5.4 Habitat enhancement

There is also a possibility of enhanced habitat by the underwater structures acting as artificial reefs and increasing fish density. This could attract piscivorous birds. There would be a net benefit only if the birds were not avoiding the wind farm and if there was no significant mortality from collisions (Drewitt and Langton 2006, Fox et al. 2006).

5.5 Collision mortality

Similar to many aspects of potential impacts of offshore wind farms on birds, the mortality from collisions is dependent on many different factors including siting, species, season, weather, and lighting. Additionally, collision risk for a particular species can vary depending on age, behavior, and timing within a breeding cycle (e.g. during feeding chicks) (Drewitt and Langston 2006).

A particular risk for birds that collide with offshore wind farms is that they are more likely to die (from drowning) than birds that collide with terrestrial turbines (Fox et al. 2006). Collisions generally occur in three ways: birds can collide with the superstructure, the rotating turbines, or are forced to the ground by the vortex created by the moving rotors (Drewitt and Langton 2006, Fox et al. 2006).

Although at some sites mortality maybe low, for long-lived species with populations already at risk the loss of a few individuals has the potential for significant population-level effects (Drewitt and Langton 2006). In particular, there could be a significant impact for birds that are k-strategist (i.e. long lived and produce few young per year). Even an additional 0.5 to 0.1% mortality could cause a decline in the population. The 1% estimate for terns in Zeebrugge, Belgium, could have a significant impact (Everaert and Stienen 2006). The impact can be exacerbated at sites where there is cumulative mortality from multiple wind farms (Drewitt and Langton 2006).

5.6 Importance of siting

The location of a wind farm can dictate the rate of collision mortality and the potential harm to a bird population. Researchers have recorded low collision rates at some wind farms, but high rates at other, poorly sited projects (Table 1) (Bright 2008). In particular, the wind farms located away from larger concentrations of birds have low collision mortality (Drewitt and Langton 2006).

Collision rates can differ significantly from site to site and from turbine to turbine within a wind farm because of a variety of factors including weather, turbine layout, topography, turbine technology, proximity to migration routes, and species present as well as species abundance (Drewitt and Langston 2006, Kuvlesky et al. 2007, and Sovacool 2009). These variables can significantly affect annual collision rates per turbine, which can range from 0.01 to 23 birds depending upon the site—some sites have recorded up to 64.3 mortalities/turbine (Drewitt and Langston 2006). Differences in turbine-to-turbine mortality is directly related to the number birds flying around turbines, indicating that site selection can play a critical role in the number of birds killed (Everaert and Stienen 2006).

Table 1. Estimates of collision mortality from Erickson et al. 2005 (MW = Megawatt)

Table 1–*Estimates of avian collision mortality by wind projects.*

Location of study[1]	No. turbines	No. MW	No. birds/ turbine/year	No. birds/ MW/year	No. raptors /turbine/year	No. raptors /MW/year
West (excluding California)						
Stateline, Oregon/Washington	454	300	1.69	2.56	0.053	0.080
Vansycle, Oregon	38	25	0.63	0.96	0.000	0.000
Klondike, Oregon	16	24	1.42	0.95	0.000	0.000
Nine Canyon, Washington	37	48	3.59	2.76	0.065	0.050
Foote Creek Rim, Wyoming	105	68	1.50	2.34	0.035	0.053
Subtotal	650	465	1.71	2.40	0.044	0.068
Upper Midwest						
Wisconsin (MG&E and PSC)	31	20	1.30	1.97	0.000	0.000
Buffalo Ridge, Minnesota	354	233	2.86	4.21	0.002	0.008
Subtotal	386	254	2.73	4.03	0.002	0.008
East						
Buffalo Mountain, Tennessee	3	2	7.70	11.67	0.000	0.000
Grand Total	1039	721	2.11	3.04	0.029	0.045
California (older projects)						
Altamont, California	~5400	548	na[2]	na	0.100	na
Montezuma Hills, California	600	60	na	na	0.048	na
San Gorgonio, California	~2900	300	2.31	na	0.010	na
Subtotal	~8900	878	na	na	0.067	na

Total fatality projections	Overall	Outside California
Projected annual bird fatalities[3]	20,000-37,000	9200
Raptors[4]	933	195

[1]We excluded studies of 4 small project sites in Vermont, Pennsylvania, Colorado, and Iowa that were conducted short-term and/or did not include adjustments for scavenging and searcher efficiency bias.
[2]Not available; data on scavenging or searcher efficiency or average MW of study turbines not available
[3]The per turbine/year and per MW/year estimates applied to the number of MW in U.S. at the end of 2003
[4]Based on the per turbine estimate in California (11,500 turbines) and the per MW basis outside California

5.6.1 Raptors

Raptor mortality at terrestrial wind farms is well documented, generally occurring at sites located within critical breeding, foraging, or migratory habitat and associated with the older lattice-type turbines—some raptors are attracted to the lattice as perching sites for hunting. These high rates of collision could potentially be reduced by using newer turbines, which have slower rotational speed and higher capacity—one new turbine could replace up to 34 of the existing units (Sovacool 2009).

In Germany, 17 white-tailed eagle (*Haliaeetus albicilla*) and 69 red kite (*Milvus milvus*) carcasses were found during a non-systematic search effort (Hotker et al. 2004 and Durr 2006 *in* Everaert and Stienen 2006). A wind farm on the Island of Smola, Norway, with

68 turbines had four white-tailed eagle deaths between August and December of 2005 (Follestad 2006 *in* Everaert and Stienen 2006). In Altamont, California, researchers estimated that 67 golden eagles (*Aquila chrysaetos*) were killed annually (Smallwood and Thelander, 2008) and in Tarifa, Spain, 35 griffon vultures were killed annually (*Gyps fulvus*) (Barrios and Rodriguez 2004). In Navarre, Spain, griffon vulture mortalities were estimated at 400 (Drewitt and Langston 2006).

5.6.2 Nocturnal migrants

During nocturnal migration, songbirds have the greatest risk of encountering and potentially colliding with wind turbines in drizzle and fog. The risk may extend to other species as well, such as whooping swans (*Cygnus cygnus*), which may collide at night with turbines during daily foraging trips between roosting and feeding sites (Larsen and Clausen 2002).

Surprisingly, there appears to be little data available on bird collisions with offshore obstacles. However, there have been documented accounts of birds colliding with lighthouses, oil rigs, and offshore marine research facilities (summarized in Huppop et al. 2006). Birds have also been observed flying around oil rigs to the point of exhaustion and colliding with fishing boats in large numbers (Doug Forcell, USFWS pers. com.).

There are few studies that have quantified songbird collisions with offshore wind turbines, but one paper on pre-construction impacts did record songbird fatalities. In the North Sea off of Germany, an unmanned research platform was deployed to study bird migration. Between October 2003 and December 2004 the platform was visited 44 times at regular intervals. A total of 13,037 birds were recorded at night by a thermal imaging camera. A total of 442 dead birds were found on the research platform, representing 21 species. Six of the birds were non-passerines (songbirds) and 87.3% of the birds collected were thrushes. The results clearly show that the birds died by colliding with the structure and only in a few cases could starvation have been a possibility. Over 50% of the deaths occurred during two nights of poor visibility. The mist and drizzle during those nights may have increased the attraction to the illuminated platform. During one of these nights thermal imaging "revealed that many birds flew obviously disoriented around the illuminated platform." Due to birds falling into the sea and being taken by scavengers, the researchers presumed that the total number of collisions was many times higher than recorded (Huppop et al. 2006).

Certainly not all the birds flying around turbines are killed. Although significantly more research is needed, one study found that 2.5% of birds flying through rotating turbines were struck (Winkelman *in* Everaert and Stienen 2006), and another study, using thermal imaging equipment, has shown that some passerines can stop briefly in front of a sweeping turbine to avoid collision (summarized in Fox et al. 2006).

5.6.3 Seabirds

Research has demonstrated that seabirds can collide with wind turbines in the marine environment. In Belgium, terns collided with turbines located on a breakwater near a breeding colony: 161 terns, mostly common (*Sterna hirundo*) and Sandwich (*Stern sandvicensis*) collided and were killed during the 2004 and 2005 breeding seasons. The mean number of terns killed was 6.7 (19.1 including all species, mostly gulls) per turbine per year for the entire 25-turbine wind farm and increased to 10.8 (27.8 including all species mostly gulls) for the turbines located on the breakwater near the breeding colony (Everaert and Stienen 2006).

5.6.4 Habituation

Although there is a possibility that wintering birds may habituate to turbines (Langston and Pullan 2003 *in* Drewitt and Langston 2006), research suggests that the longer a wind farm has operated the greater the decrease in bird abundance, i.e., that birds did not become habituated. This indicates that long-term monitoring greater than 5 years is required and that wind farms could cause larger declines in sea duck abundance over decades (Stewart et al. 2007).

5.6.5 Flight altitude

There are few studies on flight altitude during migration over the ocean, although migrants are documented to change height when encountering land (Fox et al. 2006). One study in the North Sea off the coast of Germany measured flight height with radar and found that almost half of the migrating birds fly at altitudes that could come into contact with wind turbines (Huppop et al. 2006). Additionally, a study on whooping swans (*Cygnus cygnus*) found that 38% of flocks flew at the height of medium-sized wind turbines (45 meter high towers), while 13% flew at the height of larger turbines (68 meter high towers) (Larsen and Clausen 2002).

Weather condition can affect altitude of flight (see section 5.6.7 for details). Many birds in good weather fly at altitudes well above turbine rotors, but during low cloud cover and strong head winds birds may be forced to fly much lower and potentially at turbine height (Drewitt and Langston 2006).

5.6.6 Lighting

Ornithologists commonly accept that birds are attracted to lights. Birds' attraction to illuminated structures is well documented, especially during overcast nights with drizzle and fog (Drewitt and Langston 2006). Birds appear to be attracted to continuous light in poor weather conditions (Fox et al. 2006).

5.6.7 Weather

Risk to birds can also vary with weather conditions. Birds are more likely to collide with structures during poor visibility in rain or fog (Drewitt and Langston 2006, Huppop et al. 2006). See section 5.6.2 for an example. For certain birds this may be mitigated by less activity during poor weather, but birds that are already migrating will continue to fly and will likely be forced by low cloud cover to lower altitudes, potentially flying at rotor height (Drewitt and Langston 2006).

6. Species Most at Risk

Species considered to be at the greatest risk in Europe are seabirds (Table 2), grebes, sea ducks, migrating waterfowl, and migrating songbirds (Drewitt and Langston 2006). In Maine shorebirds and raptors may also be at risk during migration.

Table 2. Seabirds determined to be most at risk in the North Sea by Garthe and Huppop (2004). A 1 (low vulnerability) to 5 (high vulnerability) rank was used for a several factors seen below. The birds with the highest species sensitivity index (SSI) values were considered most at risk.

Table 2. Score of the nine vulnerability factors and the resulting species sensitivity index (SSI) values for each of the 26 seabird species. For details see text

Bird species	Flight manoeuvrability	Flight altitude	% flying	Nocturnal flight activity	Disturbance by ship and helicopter traffic	Habitat use flexibility	Biogeographical population size	Adult survival rate	European threat and conservation status	SSI
Black-throated diver	5	2	3	1	4	4	4	3	5	44·0
Red-throated diver	5	2	2	1	4	4	5	3	5	43·3
Velvet scoter	3	1	2	3	5	4	3	2	3	27·0
Sandwich tern	1	3	5	1	2	3	4	4	4	25·0
Great cormorant	4	1	4	1	4	3	4	3	1	23·3
Common eider	4	1	2	3	3	4	2	4	1	20·4
Great crested grebe	4	2	3	2	3	4	4	1	1	19·3
Red-necked grebe	4	2	1	1	3	5	5	1	1	18·7
Great black-backed gull	2	3	2	3	2	2	4	5	2	18·3
Black tern	1	1	4	1	2	3	4	4	4	17·5
Common scoter	3	1	2	3	5	4	2	2	1	16·9
Northern gannet	3	3	3	2	2	1	4	5	3	16·5
Razorbill	4	1	1	1	3	3	2	5	2	15·8
Atlantic puffin	3	1	1	1	2	3	2	5	5	15·0
Common tern	1	2	5	1	2	3	3	4	1	15·0
Lesser black-backed gull	1	4	2	3	2	1	4	5	2	13·8
Arctic tern	1	1	5	1	2	3	3	4	1	13·3
Little gull	1	1	3	2	1	3	5	2	4	12·8
Great skua	1	3	4	1	1	2	5	4	2	12·4
Common guillemot	4	1	1	2	3	3	1	4	1	12·0
Mew gull	1	3	2	3	2	2	2	2	4	12·0
Herring gull	2	4	2	3	2	1	2	5	1	11·0
Arctic skua	1	3	5	1	1	2	4	3	1	10·0
Black-headed gull	1	5	1	2	2	2	1	3	1	7·5
Black-legged kittiwake	1	2	3	3	2	2	1	3	1	7·5
Northern fulmar	3	1	2	4	1	1	1	5	1	5·8

7. AREAS TO BE AVOIDED

By careful siting many of the concerns outlined in the above sections can be minimized. In particular, risks can be significantly reduced by avoiding feeding and roosting areas; tips of peninsulas where migrating birds concentrate (Huppop et al. 2006, Fox et al. 2006); outer islands that are strategic migration staging areas; dense migration areas (Huppop et al. 2006); any area with concentrations of vulnerable species (Drewitt and Langton 2006); high-density waterfowl and wading bird areas (Drewitt and Langton 2006); high raptor-use areas (Drewitt and Langton 2006); areas close to shore (Figure 3) (Garthe and Huppop 2004); and the intersection of migratory flyways and local foraging flight paths (Drewitt and Langton 2006).

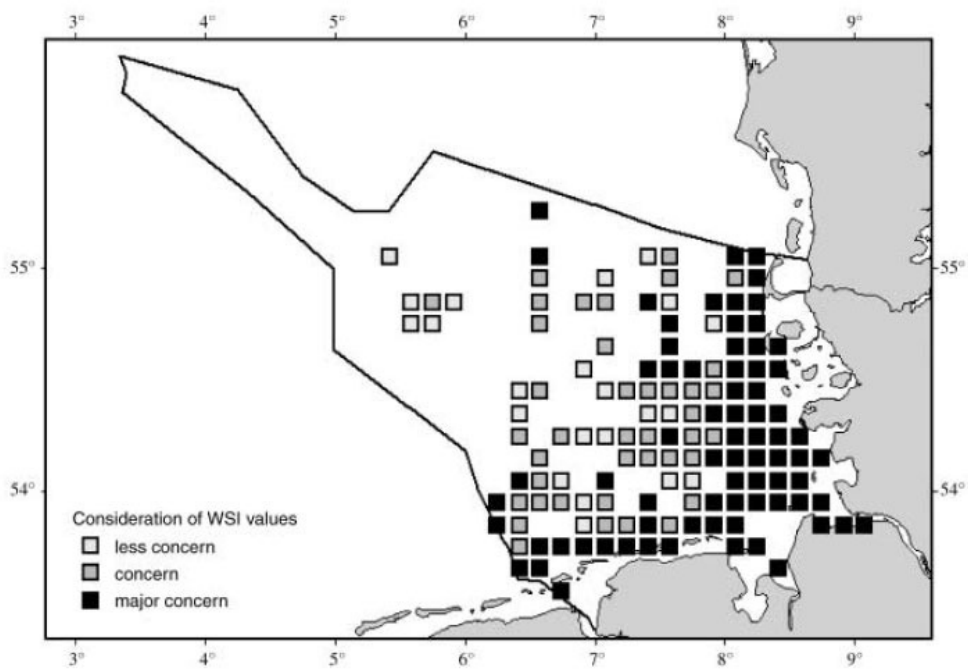

Fig. 6. Areas in the German sector of the North Sea where wind energy utilization is considered to be of 'no (less) concern', 'concern' or 'major concern'. Areas not studied in at least one of the seasons are left blank.

Figure 3. Garthe and Huppop (2004) figure shows that areas closer to shore will have greater impact upon seabirds. In Maine this analysis would also include Maine islands.

8. MAINE-SPECIFIC CONSIDERATIONS

In considering test turbine sites or large-scale offshore wind development, there are several specific considerations for Maine: 1) avoid critical breeding, wintering, and migratory areas that are currently identified; 2) avoid offshore islands that provide breeding habitat for seabirds and are particularly sensitive because they are strategic staging areas for migrants; and 3) avoid areas within 3 km of these identified areas as they should be viewed as having the potential for a high risk of impact to specific birds.

There is a significant amount of information on critical breeding and wintering habitat for many taxa of birds in Maine. The existing information can help with avoiding areas where there is the potential for increased impacts. These areas include seabird nesting islands, eagle nesting areas, mapped shorebird roosting and feeding habitat, wintering waterfowl and waterbird concentration areas, Important Bird Areas, and species of special concern use areas (e.g. piping plovers, least terns, roseate terns, great cormorants, harlequin ducks, and purple sandpipers).

Since the birds tend to forage around many of these mapped areas (e.g. an eagle nest, or a seabird island), a general buffer needs to be placed around the nest site to indicate areas where wind turbines have the potential to cause breeding failure or mortality from collision. The foraging patterns are going to vary by species and potentially change annually due to change in food availability. Consequently, a circular buffer is the best crude estimate of area of most impact.

A review of the literature will find that most seabirds, wading birds, and raptors have large foraging areas that can extend tens of kilometers. For example, Leach's storm-petrels will forage up to 200 km offshore, double-crested cormorants can forage up to 40 km, and common terns will forage daily beyond 6 km from Seal Island in outer Penobscot Bay (S. Hall, National Audubon, pers. com.). Based upon documented foraging distances, we recommend 3 km as a buffer to place around critical mapped habitat. This is a conservative estimate and site-specific studies would be necessary to determine exact foraging patterns.

9. BATS

The Gulf of Maine, with its many wooded islands and lighthouses, may contain important staging areas for migratory bats, providing essential habitat for foraging, roosting, rehydration, and copulation. Migratory bats such as the hoary bat (*Lasiurus cinerius)*, red bat (*L. borealis)*, and silver-haired bat (*Lasionycteris noctavigans*) reproduce during migration. The bats congregate at the tallest tree in a forest and at lighthouses to mate (Cryan 2007). They may also be attracted to wind turbines to mate during migration and potentially be killed.

9.1 Evidence of Maine coastal use

Little is known about the natural history and coastal use patterns of bats in Maine. However, red bats travel along the East Coast from Maine to Maryland (Miller 1897, Johnson and Gates 2008, Zimmerman 1998, Biodiversity Research Institute 2008 unpublished data). Several anecdotal records of red and silver-haired bats aboard ships at sea suggest offshore migration (Miller 1897, Norton 1930, Carter 1950, Mackiewicz and Backus 1956, Peterson 1970). Within these records, red bats were found as far as 130 miles offshore (Norton 1930) and in flocks of approximately 200 individuals (Carter 1950). Additionally, the bats are observed annually on Mount Desert Rock (S. Todd, College of the Atlantic, pers. com.).

9.2 Migration patterns

Hoary, red, and silver-haired bats could potentially encounter offshore wind farms during their latitudinal migration (Arnett et al. 2008), and are likely using navigation and orientation methods similar to birds (Holland 2007). Consequently, wind turbines could negatively impact tree bats that use the outer islands during migration.

Additionally, Maine cave species[1] may summer on islands and migrate from the islands to caves in Maine, New Hampshire, Massachusetts, Vermont, and New York for the winter. This seasonal shift potentially puts them at risk to wind power development, because they cross open water between roosting and hibernating areas.

9.3 Collision

Wind turbines may be a significant hazard to bats, especially during migration (Kunz et al. 2007, Arnett et al. 2007). In addition to direct strikes, bats can die from pulmonary lesions caused by pressure changes around turbine blades (Baerwald 2008). In August 2008, a research team from the University of Calgary released a report that identifies why bats are particularly vulnerable to turbines. They found that while bats can detect turbines through echolocation, this same ability offers no protection toward pressure drops. Of all bats that encountered turbines, 100% had pulmonary lesions and nearly all had internal hemorrhaging, regardless of external wounds.

10. HOW TO REDUCE IMPACTS

There are many specific design and operational considerations that can dramatically reduce the impacts of wind farms on birds.

10.1 Design considerations

10.1.1 Turbine array alignment

To minimize the development footprint, site turbines close together (subject to technical constraints such as the need for greater separation between larger turbines). To avoid alignment perpendicular to main flight paths and to provide corridors between clusters,

[1] Little brown (*Myotis lucifugus*), northern long-eared (*M. septentrionalis*), eastern small-footed (*M. leibii*), and big brown bats (*Eptesicus fuscus*)

group turbines (Drewitt and Langston 2006) and align them in rows parallel to the main migratory direction (Huppop et al. 2006). Free migration corridors by leaving several kilometers between wind farms (Huppop et al. 2006).

10.1.2 Rotor visibility

Increase the visibility of rotor blades (Huppop et al. 2006). Research indicates that high-contrast patterns might help reduce collision risk and painting the rotor blades with UV paint may enhance their visibility to birds (Drewitt and Langston 2006).

10.1.3 Lighting

Refrain from having large-scale continuous illumination (Huppop et al. 2006). White flashing lights (strobes) appear to be better than red lights (Doug Forcell, USFWS pers. com.) and generally, the less lighting the better. If Coast Guard and FAA regulations allow, consider lighting as few turbines as possible in an array (e.g. only the outer ones).

10.2 Adaptive management

Turn off turbines during nights predicted to have adverse weather and high migration intensity (Huppop et al. 2006). Both onsite directional radar and weather radar can be used to detect large movements of migrants. Turbines could be turned off for short time periods of greatest bird-collision risk.

Although potentially prohibitively expensive, move or remove specific “problem” turbines if they are causing a higher rate of mortality than other turbines within a wind farm.

10.3 Best practice measures

Drewitt and Langston (2006) suggest several best management practices that could generally reduce impacts. They are:

1. Provide adequate briefing for site personnel and, in particularly sensitive locations, employ an on-site ecologist during construction.
2. Implement an agreed post-development monitoring program through planning or license conditions.
3. Implement appropriate working practices to protect sensitive habitats.
4. Carefully time and route offshore maintenance trips to reduce disturbance from boats, helicopters, and personnel.
5. Install transmission cables underground (subject to habitat sensitivities and in accordance with existing best practice guidelines for underground cable installation).
6. Schedule construction to avoid sensitive periods.
7. Mark overhead cables using deflectors and avoid use over areas of high bird concentrations, especially for species vulnerable to collision.

10.4 Mitigation

Despite best efforts in siting and development, there will likely be some impacts on birds and bats. Properly designed and implemented mitigation plans could reduce these impacts. Although mitigation measures would need to be species specific, some potential efforts are as follows (Doug Forcell, USFWS pers. com.):

- Locate and remove lost fishing nets that are causing bird mortality
- Fund increased law enforcement of illegal take of birds
- Fund gear and fishery modifications to reduce bird bycatch
- Protect sensitive habitat such as seabird nesting islands

11. MONITORING METHODOLOGIES

In Europe recently there have been developments of techniques for monitoring bird movements at potential sites and within existing wind farms. Detailed methods on survey methods and considerations are available in Fox et al. 2006 (in suggested reading). These techniques aim to quantify collision impacts, avoidance, and behavior.

Generally, to assess impacts of wind farms on birds researchers should collect data on bird numbers, distribution, and movement (Drewitt and Langton 2006). Baseline or pre-construction surveys should at a minimum be two years, and post-construction surveys should be three to five years in order to account for annual variation (Huppop et al. 2002 *in* Fox et al. 2006).

Specifically, to gauge collision mortality researchers should assess the volume, direction, and altitude of birds flying in the proposed area as well as predict the number of collisions in different seasons and weather conditions. Collectively, this monitoring must consider cumulative impacts and the impacts on regional and global populations (Fox et al. 2006).

Within a potential development site, assessment should include data on distribution and abundance of foraging and migrating birds, a prediction of how different species will avoid turbines, and a comparison of post-construction effects to pre-construction predictions (Fox et al. 2006).

11.1 Surveys

It is necessary to conduct extensive surveys of birds within marine waters to assess a proposed site's relative importance to different bird taxa. Ideally, these surveys would cover as large an area as possible and be conducted simultaneously. Researchers can conduct surveys in a systematic grid pattern from stationary platforms, boats, and aerially. If conducted systematically the data can be used for spatial modeling (Fox et al. 2006).

11.2 Radar

Marine boat radar is an effect technique of monitoring birds within 11km of a site. It allows for continuous monitoring during both the day and night, and through the use of vertical and horizontal systems can record both flight altitude as well as flight direction. It is of limited use, however, during precipitation. Larger surveillance and tracking radar has a greater range and can provide detailed movement patterns of flocks, but is expensive and more difficult to use than marine radar (summarized in Drewitt and Langston 2006). These types of radar have a range up to 200km and include military, weather, and air traffic equipment (Fox et al. 2006)

11.3 Thermal Animal Detection Systems (TADS)

These infrared video camera are being used in Denmark to record the movements of birds within close proximity of turbines. This technology can be used to generally detect the types of birds around turbines through flight behavior, size, and other factors. These systems can also be used to detect collisions with rotors (summarized in Drewitt and Langston 2006).

11.4 Other technology

There are other remote systems that are being developed to detect bird movement. These include pressure and vibration sensors mounted in turbine blades to detect bird strikes. There is also the development of acoustic monitoring equipment to detect bird movement from their calls (summarized in Drewitt and Langston 2006).

11.5 Population modeling

Ultimately, the most important aspect of assessing impacts on birds is determining whether there is a population-level impact from collision mortality, avoidance, or habitat loss. Developing models requires gathering a vast amount of data followed by the collecting data to validate models. An example of this type of work can be seen at www.offshorewindfarms.co.uk (Drewitt and Langston 2006).

12. RECOMMENDATIONS

A theme in the review of impacts is the high variability of potential impacts, based upon species, season, and weather. Since the decisions about siting of test and commercial wind development in Maine will need to be made with limited data, we suggest that a Bird and Bat Advisory Board be formed consisting of scientists from state and federal agencies as well as NGOs. This board would draw upon the decades of experience of researchers who have extensively studied different taxa in Maine, to help with siting and monitoring protocols.

Throughout the literature, researchers offer recommendations based upon their experience. There are two general conclusions: 1) impacts from wind farms can be significantly reduced with proper siting, and 2) pre-construction baseline research is critical in reducing potential impacts (Langston and Pullan 2004, Drewitt and Langston 2006, Fox et al. 2006, National Academy of Sciences).

Specific comments are as follows:

- "At the preliminary stage of a development proposal it is clearly important to use existing information to determine the likelihood of impacts. Ideally this would be undertaken in a pre-emptive, strategic way, collecting information to identify those areas where there are unlikely to be significant impact on birds" (Drewitt and Langston 2006).

- "It is important to stress the need for adequate base-line and post-construction sampling" (Fox et al. 2006).

- Everaert and Stienen 2006 recommend that there should be "precautionary avoidance" of building wind turbines close to breeding colonies of gulls and terns, that artificial breeding habitat should not be built near turbines, and, in particular, turbines should not be placed within frequently used flight paths.

- Kaatz (2002 *in* Everaert and Stienen 2006) recommends that large wind turbines should not be built along the coast because of the large potential numbers of small birds that could be killed as well as the barrier effect to migration.

- "An exhaustive study before the selection of future wind farm locations is a key factor to avoid deleterious impacts of wind farms on birds." (Everaert and Stienen 2006).

- A precautionary approach should be adopted to wind farm development near aggregations of wildfowl (Anseriformes) and waders (Charadriiformes) in offshore and coastal locations (Stewart et al. 2007).

13. Suggested Reading

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