Wind Energy: Great Lakes Regional Guidelines

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Executive Summary and Synthesis of Siting and Operational Guidelines

Given the rapid and projected increase in wind energy development in the United States (Department of Energy 2008), including the Great Lakes states of Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York, a broad interest exists for developing specific guidelines for placement and operation of wind turbines that minimize impacts on species, communities, and ecological systems. This demand has been addressed by many agencies through their own pre- and post-construction guidelines (see Section VII A and B). Previous guidelines provide general guidance for siting and/or recommended protocols for monitoring, but the underlying documentation and caveats for these recommendations is often not provided or made explicit.

Here we provide recommendations for wind energy siting and operation for birds, bats, and communities based primarily on peer-reviewed literature and published reports (summarized in Tables 1-2). A discussion of the literature used to derive these recommendations is presented in subsequent sections of this report. Readers are strongly encouraged to review the scientific rationale used to develop these guidelines. We recognize that much remains unknown regarding interactions of species, communities, and ecological systems relative to wind energy production. We emphasize that these recommendations are strongly based on minimizing risk to species, communities, and ecological systems, as empirical data to support these recommendations are sparse.

One outcome of this effort will be to sharpen the focus of research and monitoring efforts so that more empirical data can be used to provide guidance on wind energy siting in the future (Section V). This underscores the need for pre- and post-monitoring efforts to refine these guidelines. Standardized data collection and having a central database to house results from research would facilitate synthesis of information and help resolve currently inadequately understood interactions between wind turbine placement and regional biota and ecological systems.

We emphasize that those using these guidelines also coordinate with or review information from federal, state and local governments and non-governmental organizations as early as possible to avoid risks to sites with high biological value.

Table 1. Siting Recommendations. At least some of the caveats associated with these recommendations are discussed in Section IV; there may be others. Research needs required to resolve these caveats are listed in Section V. In particular, cumulative effects at local to large spatial or temporal scales have not been quantified.

Guideline	Justification	Sections/Key Citations
Sensitive biodiversity sites. Avoid sites with state and federally threatened or endangered species or lands designated or appropriate for biodiversity conservation.	This will help abate loss of threatened and endangered species and ecologically important lands.	Section IV B; data on distribution of listed species is housed with Natural Heritage Programs and U.S. Fish and Wildlife Service.
Birds. Avoid areas where large numbers of migrating birds concentrate (e.g., Audubon	Placing wind turbines, or other large structures, where relatively large numbers of birds occur increases the	Section IV C.1

Important Bird Areas [IBAs]) or where large numbers of migrating birds are predicted to occur (Ewert et al. 2005).	risk of collision and may have both local and cumulative consequences for bird populations. IBAs are sites with rare and/or threatened bird species, significant species assemblages, and high concentrations of migratory birds.	
Birds. Avoid Audubon IBAs for breeding birds, terrestrial and aquatic.	Avoiding IBAs important to breeding birds will help abate direct mortality and habitat loss.	Section IV C.1,3,9. National Audubon Society 2010
Birds. Follow draft U.S. Fish and Wildlife Bald and Golden Eagle management guidelines.	Minimize take and disturbance to eagles throughout their life cycle.	Section IV C.1. U.S. Fish and Wildlife Service 2007a
Birds. Avoid areas within 2 miles (3.2 km) of breeding federally-listed or candidate bird species, or U.S. Fish and Wildlife Service designated critical habitat for such species.	Minimize effects on these species. Additional study is needed to provide more explicit recommendations.	Section IV C.1
Great Lakes Open Waters. Avoid cross-lake migratory bird routes and pelagic staging areas.	Some geographic features (e.g., peninsulas, chains of islands, ridges) have concentrations of migrating birds. Avoiding development in such areas will abate direct mortality and habitat loss of migratory birds.	Section IV C.1,3; Petersen et al. 2006; Hüppop et al. 2006; Drewitt and Langston 2006; Lott et al. 2011
Great Lakes Open Waters. Avoid important fish spawning and nursery areas; infrastructure in these areas should be minimized or avoided.	Disturbed sediments from turbine construction can be lethal to fish eggs and larvae, and construction can attract predators to nursery grounds. Avoiding spawning/nursery areas will help protect fish habitats.	Section IV C.3; Engell-Sorensen and Skyt 2001; Söker et al. 2000; Smith and Westerberg 2003
Coastal. Avoid wind energy development within 5 miles (8 km) of Great Lakes shorelines, including islands, and including agricultural fields traditionally used by large numbers of waterfowl.	Coastal areas support high concentration of migratory birds. The buffer will help abate direct mortality of birds and protect coastal stopover habitats.	Section IV C.3-4; Cooper et al. 2004; Bonter et al. 2009
Grasslands. Avoid grasslands > 76 acres (30 ha); maintain a buffer of 660 ft (200 m) around these grasslands.	Grassland bird species are differentially sensitive to habitat fragmentation. This buffer will help abate area abandonment of species highly sensitive to habitat fragmentation and turbines, especially Henslow's Sparrow.	Section IV C.5; Sample and Mossman 1997; Herkert 2003; Robel 2002; Guarnaccia and Kerlinger 2007
Grasslands. Avoid areas within 1 mile (1.6 km) of grassland edges	Greater Prairie-Chickens, a rapidly declining species, occur in	Section IV C.5; Robel 2002

where there are Greater Prairie-Chickens.	Minnesota, Wisconsin, and Illinois and are highly sensitive to fragmentation.	
Grasslands. Avoid prairie and savanna remnants of any size.	Native prairie and savanna remnants are very rare and support rare plant and animal populations	Section IV C.5; Panzer et al. 2010
Forests. Avoid reducing forest cover <75% in largely intact landscapes; avoid forest patches >5,080 acres (>2,000 ha) in agricultural or urban landscapes; in highly altered landscapes with <20% forest cover avoid additional forest loss and retain buffers of 0.25 miles (400 m) around forest patches >2.5 acres (1 ha) and buffers of 0.12 miles (200 m) around patches <2.5 acres (1 ha).	Many declining and threatened bird species are susceptible to habitat fragmentation, edge-effects, and behavioral responses to turbine construction. Avoiding large habitat patches will help maintain viable populations. Avoiding small, isolated forest patches in highly altered landscapes provides stopover sites for migrating birds.	Section IV C.5,6; Mancke and Gavin 2000; Robinson et al. 1995; Mehlman et al. 2005
Inland Wetlands. Avoid areas within 1,980 ft (600 m) of inland wetland complexes >2.5 acres (1 ha); avoid separating herpetofauna breeding areas from non-breeding habitat.	Many amphibians and reptiles disperse relatively long distances from water. This buffer will help abate habitat destruction and fragmentation for vulnerable herpetofauna and, also, Whooping Cranes and migrating waterfowl.	Section IV C.7; Lee 2000; McDonough and Paton 2007; Minnesota Department of Natural Resources 2010; University of Rhode Island 2001; Guarnaccia and Kerlinger 2007
Riparian Areas. Avoid areas within 0.12-0.31 mile (200-500 m) of riparian corridors, depending on the size of the river (stream order).	Riparian corridors provide habitat for migratory landbirds, bats, and many semi-aquatic species, including reptiles and amphibians, and may be especially important in fragmented landscapes.	Section IV C.8; Ficetola et al. 2009; Ohio Department of Natural Resources 2009; Guarnaccia and Kerlinger 2007

Table 2. Operational Recommendations. At least some of the caveats associated with these recommendations are discussed in Section IV C.10; there may be others. Research needs required to resolve these caveats are listed in Section V. In particular, cumulative impacts of these guidelines over large spatial or temporal scales have not been quantified.

Guideline	Justification	Sections/Key Citations
Turbines should be feathered during peak bird migration periods when weather conditions associated with low altitude flight occur, such as fog.	Especially during peak migration periods, poor weather (e.g., fog, rain) may force nocturnally migrating birds to fly at lower altitudes and increase risk of collision. Feathering turbines should help abate direct mortality of migratory birds during such	Section IV C.3,10; Hüppop et al. 2006; Drewitt and Langston 2006

	conditions.	
Turbines should be feathered when wind speeds are below 18.1 ft/sec (5.5 m/sec) between sunset and sunrise during fall bat migration and swarming.	Bat mortality is highest on low windspeed nights in the fall; feathering turbines during these times dramatically decreases bat mortality.	Section IV C.2,10; Arnett et al. 2010, 2011
Turbines should be intermittently, rather than continuously, lighted.	Large-scale, continuous lighting may attract birds to wind turbines, especially during poor weather. Intermittent Federal Avian Administration lighting may help abate direct mortality of migratory birds.	Section IV C.3,10; Kerlinger et al. 2010; Hüppop et al. 2006; Winkelman 1992a-d; Gehring et al. 2009

I. Introduction

There is a need to develop specific guidelines for placement of wind turbines that minimizes impacts on species, natural communities, and ecological systems given the rapid and projected increase in wind energy (see Kiesecker et al. 2011) and potential impact on terrestrial (McDonald et al. 2009, Kiesecker et al. 2011) and aquatic landscapes (Gill 2005). Though there are many efforts to provide this guidance (see Section VII), there has been no synthesis of Great Lakes regional guidelines emphasizing the underlying scientific basis for these recommendations. The objective of this work is to provide specific guidelines for the siting and operations of wind energy facilities based upon the best available data and knowledge for the Great Lakes states and Ontario, including the Great Lakes open waters and Great Lakes shorelines, areas that have particularly high potential for wind energy production.

These guidelines are intended to assist those planning for or responding to utility-scale wind energy facilities. We recognize the value of wind energy production for biodiversity conservation, and intend for these guidelines to maximize compatibility of wind energy production with maintenance of biodiversity. Wind energy developers, landowners, governmental and NGO staff charged with protecting biodiversity, and other stakeholders can use this report to minimize the possible impacts of turbine construction on species and ecological systems.

The recommendations summarized here represent the first in-depth, evidence-based synthesis of recent scientific information for birds, bats, Great Lakes waters, Great Lakes shorelines, forest, grasslands, inland wetlands, riparian areas, and agricultural lands related to wind energy development in the Great Lakes region. They provide specific guidance for siting and operating wind turbines to minimize impacts on these taxa and ecological systems. Recommendations for siting wind turbines should be applicable to all of the following states and province: Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania, New York, and much of Ontario. However, guidelines will be subject to different federal, state, and provincial legislation and considerations. These guidelines are *not* policy or directives, nor do they consider economic/social issues such as viewscapes.

These guidelines were developed for use at multiple spatial scales, and should be applicable at the site or project level. For a discussion of identification of potential wind turbine and infrastructure siting at coarser scales, and potential mitigation activities, see Kiesecker et al. (2009).

The recommendations in this report are based on (1) peer-reviewed literature; (2) gray literature, including reports; (3) ecological models; (4) expert opinion; (5) other biodiversity assessments and summaries (e.g., ecoregional plans); and (6) guidelines, or draft guidelines, prepared by the U.S. Fish and Wildlife Service, Government Accounting Office, Great Lakes state and provincial governments, and non-government agencies. They complement more generalized recommendations provided by the U.S. Fish and Wildlife Service and state and provincial agencies.

These guidelines are designed to minimize negative impacts of wind energy development on biodiversity. This includes, but is not limited to, species already protected by U.S. federal laws such as the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act and comparable state and province legislation. It also includes species that are rare or threatened, or thought to be in decline, but without legal protection, and natural communities.

This report is organized by section, with Section I being this introduction to the report. In Section II we list the taxa and natural communities covered in this report. Section III is an overview of potential or known threats to species and natural communities related to wind energy development. Section IV provides a discussion and synthesis of literature we reviewed to define guidelines designed to minimize negative interactions between wind energy development and biologically sensitive areas, organized by taxa and coarse-scale natural communities. In Section V, we provide a partial list of information gaps or research needs that would better inform placement and operation of wind energy facilities. Acknowledgements are in Section VI. We provide a list of additional sources of information in Section VII. A list of literature cited in the report appears in Section VIII.

II. Ecological Focus

For this report, we focus on taxa and natural communities, described in the Great Lakes ecoregional plan (The Nature Conservancy 1999), and the Lake Ontario (Lake Ontario Biodiversity Strategy Working Group 2009) and Lake Huron (Franks Taylor 2010) lakewide basin plans. Whenever possible, we nested recommendations for species and natural communities within the ecological system where they are most commonly found. However, many bat and bird species have common concerns across systems, so this information is presented in separate bird and bat sections. The taxa and natural communities covered here include birds; bats; Great Lakes open waters; Great Lakes coast, shorelines, and islands; grasslands; forests; inland wetlands; riparian systems; and agricultural lands. These taxa and natural communities were selected for review because of their relatively high potential for interaction with wind energy development. We also include guidelines for turbine operation, with particular reference to birds and bats.

These guidelines, even when based on data from studies outside the Great Lakes region, were developed in the context of the specific species and systems of the Great Lakes region. When data on the specific Great Lakes system or species were unavailable, we have incorporated information from elsewhere in the country or the world. However, we have interpreted these data for the specific ecological filters of the Great Lakes region.

III. Overview of Biological Interactions with Wind Turbine Siting

Potential biological impacts from wind energy include (1) direct mortality, (2) long-term habitat loss and population extirpation, (3) fragmentation and associated effects on species and ecosystem processes, (4) behavioral responses to presence and operations of turbines, such as barrier effects, displacement, avoidance, responses to light-shadow "flicker," and responses to vertical structures by species such as Lesser Prairie-Chicken (*Tympanuchus palldicinctus*) (and extrapolated to Greater Prairie-Chicken [*T. cupido*]) and Henslow's Sparrow (*Ammodramus henslowii*), and (5) short-term habitat loss during construction. These impacts may occur because of turbine operation, maintenance-related activities, or infrastructure. These factors may create or interact to create impacts that vary in magnitude, extent, duration, intensity, timing, probability, and cumulative effects.

Overall, it has been estimated that 3-5% of the area of commercial wind turbine development is habitat loss due to construction, while 95-97% of the impact area is from fragmenting habitats, species avoidance behavior, and issues of bird and bat mortality (McDonald et al. 2009). Fragmentation can have many different types of effects and is created by many activities other than wind energy production. Wildlife interactions with wind power are expressed at varying distances from wind turbines and associated infrastructure such as towers, roads, and transmission lines. Fragmentation can result in low relative abundance, low productivity, changes in microclimate and thus species composition, spread of invasive species, changes in behavior (including avoidance, displacement, foraging), or other factors that reduce or eliminate populations or degrade natural communities.

However, the relative importance of these interactions will vary by landscape features, ecological system, and site. Fragmentation consequences operate at landscape and site scales and affect all taxa, although different taxa may be more or less susceptible to fragmentation; amphibians (see Cushman 2006) and reptiles, for example, are often considered to be especially vulnerable to fragmentation, even very locally. Direct mortality due to collisions will affect taxa using the air column (i.e., birds and bats, perhaps especially bats). Therefore, we consider these threats separately for each ecological focus.

IV. Wind Energy Siting Guidelines

A. Sites That May Be Suitable for Siting of Wind Turbines

Some landscapes support a relatively depauperate and/or highly altered biota and thus may be likely sites for wind turbine placement and associated infrastructure (see Kuvelsky et al. 2007; Kiesecker et al. 2011). However, many of these sites will likely need additional biological evaluation to account for bat movements, for example, which are poorly known (Section IV C.2). Suitable areas may include:

- Tilled agricultural lands distant (≥ 5 mi [≥ 8 km]) from the Great Lakes' waters with no known or suspected species migration stopover sites (see Sections IV C.1-2). Bats, in particular, move through agricultural landscapes, and these movements are poorly understood, so we suggest that monitoring for bats be done prior to development in these landscapes. Operational guidelines (Section IV C.10) should be followed if siting is deemed appropriate.
- Industrial lands, especially those distant (> 5 mi [> 8 km]) from the Great Lakes' waters.
- Brownfields, abandoned or underused industrial and commercial facilities and land available for re-use, especially those distant (> 5 mi [> 8 km]) from the Great Lakes' waters where birds are less likely to be concentrated (Section IV C.4).

B. Sites That Should Be Avoided for Siting of Wind Turbines: An Assessment and Recommendations

Lands and waters not available or less suitable for wind development include officially designated lands in which wind energy development is not permitted (e.g., wilderness areas), lands explicitly established for biodiversity protection, and other protected lands important for biodiversity. Lands without legal protection may also have ecological attributes associated with important biodiversity areas and thus may be less suitable for wind energy development. At sites where mitigation, restoration, or other actions can preserve biodiversity values, and where wind energy is permitted, some development could occur (Kiesecker et al. 2009). A partial list of sites to avoid (taken from many of the sources of Sections VI A-B) includes:

- Legally protected or otherwise designated lands associated with important biodiversity areas, some of which are closed to development in whole or in part.
    - National parks
    - Wilderness areas
    - U.S Fish and Wildlife National Wildlife Refuges
    - U.S. Fish and Wildlife Waterfowl Production Areas
    - Designated critical habitat or other management areas for threatened or endangered species
    - Habitat Conservation Areas
    - National forests
    - State parks
    - State wildlife management areas
    - Natural areas or other designated lands for natural features
    - State or federal bottomland preserves
    - Nature reserves of land trusts
    - Lands with conservation easements

- Lands with ecological/biological/physical attributes associated with important biodiversity areas but not legally protected or otherwise designated (see sources listed in Sections VII A-B).
    - Habitat for rare species (state or federally listed)
    - Ecoregional and other biodiversity sites identified by The Nature Conservancy, Ducks Unlimited, and others
    - Sites with high ranked state or globally ranked species or communities, based on Natural Heritage Program data
    - Islands with high biodiversity values, as scored by the Great Lakes Island Collaborative

- Important lands for biodiversity identified in state wildlife action plans
- Large relatively intact landscapes (> 5,000 acres [1,970 ha]) with intact ecological processes that support area-sensitive species, surrounded by moderately to highly altered landscapes
- Habitats particularly sensitive to disturbance such as beaches and sand dunes, wetlands, prairies, and open peatlands
- River mouths with large amounts of annual discharge
- Zones of high aquatic productivity

It has also been suggested that construction be minimized during migration and spawning and to minimize acoustic disruption of aquatic life and sediment disturbances that increase turbidity. Best Management Practices defined by local, state, provincial, and federal governments for erosion and sediment control should be followed. Maintaining natural drainage patterns, hydrology, surface and ground water levels, and buffers around wetlands consistent with federal/state/provincial wetland laws should be achieved.

C. Recommendations for Wind Turbine Siting

In this section, we separate the Great Lakes region into generalized ecological systems or taxonomic groups that could be affected by turbine construction, operation, and/or maintenance. Here we provide our rationale for these recommendations based on our review of the literature. For each system we present a short, synoptic ecological background relative to wind energy considerations followed by recommendations for siting and operation within that system. Even though these ecological systems are not independent of each other, we structured our recommendations by these ecological features to facilitate decision making. However, risk for some taxa need to be evaluated independently of ecosystem boundaries. Specifically, birds and bats migrate long distances, perhaps irrespective of the landscape type, and may be at risk during flight. Bald eagles also nest in a variety of habitat types and require large protective buffers, spanning a variety of ecological systems. Therefore, we first consider threats to these groups independent of ecosystem type, in two sections: (1) birds, including songbirds and raptors, and (2) bats. We then examine threats to all vulnerable taxa within specific ecological systems: (3) Great Lakes open waters (nearshore and offshore), which includes waterbirds, waterfowl, shorebirds, and landbirds; (4) terrestrial Great Lakes shorelines, coastal areas, and islands, including colonial nesting waterbirds (cormorants, herons, egrets, gulls, terns, etc.); (5) grasslands; (6) forests; (7) inland wetlands; (8) riparian areas; and (9) agricultural lands. We included recommendations on birds and bats within the ecological system whenever possible.

Although we rarely note specific species, except for bats and birds, which are thought to be especially sensitive to wind turbines because of their use of the air column (Arnett et al. 2007), we used considerable species-specific data to develop guidelines for ecological systems. While the recommendations are as explicit as possible, application will always require review to account for site- and landscape-specific conditions and new information.

These guidelines are intended to be modified as needed according to the specific site and landscape conditions. Within the Great Lakes region, there is considerable variation in landscape factors such as the degree and extent of human impact. There are also species sensitive to wind energy development whose ranges are restricted to certain portions of the Great Lakes region. Accordingly, these guidelines should be modified to take these factors into account, with the aim of preserving the biodiversity and ecological integrity of the site and landscape.

We recommend that all potential sites for wind energy development conduct rigorous, transparent, and consistent pre- and post-construction monitoring (Kunz 2007a, b; U.S. Fish and Wildlife Service Wind Turbines Guidelines Advisory Committee 2010). General guidelines for determining the suggested intensity of pre- and post-construction studies, proportional to the perceived risk at the site, have been established under the U.S. Federal Advisory Committee Act (U.S. Fish and Wildlife Service Wind Turbines Guidelines Advisory Committee 2010), and several specific sets of guidelines have been developed by states (e.g., New York State Department of Environmental Conservation 2009, Ohio Department of Natural Resources 2009, Pennsylvania Game Commission 2007). We also recommend that the results of these pre- and post-construction monitoring efforts be made publicly available to allow cross-site comparisons and thus increase our power to predict risk at potential development sites. Ontario has developed a web database into which all future data collected in Ontario will be deposited and made available (Peter Carter, Ontario Ministry of Natural Resources, personal communication). We recommend that similar infrastructure be developed and used in the United States. Consistent, transparent studies across a range of sites will help elucidate critical research needs and allow the development of wind resources while minimizing negative effects on sensitive and important species, communities, and landscapes.

These guidelines should evolve. These recommendations are based on the best information currently available. However, for some guidelines, further study could refine our estimates of the spatial scale at which biological interactions with wind turbines occur. These guidelines should be periodically reviewed and updated to account for new information.

C.1. Birds

<u>Introduction</u>
Interactions of birds with wind energy development have focused on direct effects (e.g., direct mortality from collisions), and indirect effects (e.g., displacement, effects on productivity). Responses to these interactions have been evaluated on two principal criteria, mortality and risk. Risk assessments have been made primarily by extrapolating results from sites with empirical data to sites with similar characteristics to estimate relative risk among sites being considered for wind energy. Effects on populations of birds due to collisions with wind turbines, though thought to be minimal for many species, are not known.

In this section, we focus on the location of birds during migration, including the atmosphere, and avian species that have special protected status which could be vulnerable to wind power development in the Great Lakes region and that may be found in a wide range of habitats.

Although estimates are coarse, it is thought that the Great Lakes states and provinces host ten to perhaps hundreds of millions of migrating birds, including waterbirds, waterfowl, shorebirds, raptors, and songbirds, each spring and fall (Ewert et al. 2005). Migrating birds are often concentrated near water (Ewert and Hamas 1996, Ewert et al. 2005, Bonter et al. 2009), especially the Great Lakes (Ewert and Hamas 1996, Goodrich and Smith 2008), where wind energy production potential is high (U.S. Department of Energy 2011). Consequently there is relatively high potential for interactions between migrating birds and wind energy development. Where avian distribution is system-dependent, as with breeding birds in forests or grasslands, we discuss potential avian response to wind energy development in each of the system sections: Great Lakes coastal zone, terrestrial shorelines and islands waters, forests, grasslands, riparian corridors, and agricultural lands (Sections IV C.3-9).

Because the height of migration is not known to vary as a function of terrestrial habitat type, we consider interactions of birds with wind turbines migrating over land in this section. Most nocturnal migrating landbirds fly at heights exceeding the upper reaches of the rotors of wind turbines (Gauthreaux 1972, Klaassen and Biebach 2000) and are at relatively low risk of encountering rotating blades during migration. Birds arriving on the Gulf Coast flew at greater heights over land compared to water, and 3,000 feet (900 m) higher during the day compared to night (about 50% of migrants were between 796-1,592 ft [242-485 m] above land, an altitude well above current rotor-swept areas [Gauthreaux 1972]). Cruising altitude of migrants in Israel was reported to be primarily between 6,700-13,400 ft (2,000-4,000 m) above ground in spring and 1,667-5,000 ft (500–1,500 m) in autumn (Bruderer et al. 1995). Nocturnal migrants flying above a 3,500 ft (1,045 m) elevation West Virginia ridge flew an average of 1,367 ft (410 m) above the ridge, but on five nights the mean altitude of migrants was within the rotor swept zone. Three of these nights had precipitation and/or low clouds and variable winds and direction (Mabee et al. 2006). Although few studies have documented the altitude of migration above ground in the Great Lakes region, one study conducted near Chautauqua, New York (about 3.7 miles [6 km] south of Lake Erie), found that mean nocturnal flight altitudes were about 1,757 ft (530 m) above ground during both spring and autumn migration; only 4% of the migrants were flying within the zone of risk from 3–417 ft (1–125 m) above ground level (Cooper et al. 2004). Diurnal migrants in the Great Lakes region, based on anecdotal evidence, may migrate at lower altitudes above ground than nocturnal migrants, but documentation of relative height of migration is poor.

Angle and rates of ascent and descent from stopover sites have received little attention. Along the Gulf Coast of Louisiana, Gauthreaux (1972) indicated that spring migrants “plummeted from great heights into the trees” at coastal sites when they encountered rain or adverse winds. Similarly, in Israel, Bruderer et al. (1995) noted that the “main final landing phase of nocturnal migrants is probably so steep and fast that it escapes normal recording procedures” and did not document rates of descent. Rates of ascent of migrants averaged 3 ft/sec (0.9 m/sec [as low as 0.3 ft/sec [0.1 m/sec]) in spring and 1.7 ft/sec (0.5 m/sec [as low as 0.3 ft/sec [0.1 m/sec]) in autumn in Israel (Bruderer et al. 1995); more birds were ascending than descending at dusk, but the number of birds ascending and descending was about the same the rest of the night. At an inland site in New York, Able (1977), using tracking radar, recorded that the mean angle of ascent for 18 individual passerines during spring migration ranged from 3.3°–28° for individuals steadily ascending, and mean rate of descent for three individuals steadily descending ranged from 8.8°–25.3°. The change in altitude was 10.6–146.5 ft/sec (3.2–44.4 m/sec) in spring and 51.8–56.8 ft/sec (15.7–17.2 m/sec) in autumn. These data suggest that birds would be out of the range of rotating rotors quickly and over short distances. However, in Minnesota, thousands of passerines have been noted to fly within 165 ft (50 m) of the canopy at least 3.5 miles (5.8 km) inland, perpendicular to

Lake Superior, for two or more hours after sunrise during fall migration (Anna Peterson, University of Minnesota, personal communication). Our understanding of the variability of the angles or rates of ascent and descent at any one site, under different weather conditions, and among different sites is very poorly known, even though this is critical information needed to define buffer zones (Section V).

Bird species that could be affected by wind power development, and are of particularly high conservation concern, include eagles and threatened and endangered species. Federally listed species that regularly occur in the Great Lakes region include Whooping Crane (*Grus americana*), Piping Plover (*Charadrius melodus*), and Kirtland's Warbler (*Dendroica kirtlandii*) (U.S. Fish and Wildlife Service 2010a). The distribution of state or province-listed species can be accessed from each jurisdiction, breeding bird atlases, and the Breeding Bird Survey of the U.S. Fish and Wildlife Service. Lists of other bird species of conservation concern can be found at websites of Partners in Flight, the National Audubon Society, American Bird Conservancy, Upper Mississippi River/Great Lakes Region Joint Venture, and the U.S. Fish and Wildlife Service (birds of conservation concern). Other species may also be affected by wind power development, including native, migratory species which are protected by the Migratory Bird Act.

Of the three federally listed bird species (U.S.) found in the Great Lakes region, at least Whooping Cranes and Kirtland's Warblers have been documented to collide with tall structures or power lines. Collisions with power lines are considered to be the highest source of mortality for Whooping Cranes (Lewis 1995). One Kirtland's Warbler struck the lighted Perry's Monument on South Bass Island, Ohio (Mayfield 1960). For Whooping Cranes, special precaution is needed to avoid placing wind turbines near areas that are used consistently in migration, such as the Jasper-Pulaski Fish and Wildlife Area, Indiana, and near the newly established breeding population at Necedeh National Wildlife Refuge, Wisconsin (Joel Trick, U.S. Fish and Wildlife Service, personal communication), and perhaps other wetland complexes south and east to Horicon National Wildlife Refuge and Madison, Wisconsin. There are no empirical data to define a buffer zone around these stopover and breeding areas, however. Because many Kirtland's Warblers have been located near the shoreline of the western basin of Lake Erie (Michael Petrucha, Michigan Department of Natural Resources, and Paul Sykes, personal communication), they may be relatively susceptible to collisions as they ascend or descend to stopover sites, or by striking lighted turbines in this area compared to other parts of the Great Lakes region. Kirtland's Warblers may also be susceptible as they arrive or depart from breeding grounds. As with Whooping Cranes, however, there are no empirical data to specify buffer distances from breeding grounds or disproportionately used stopover sites. There are insufficient data to define buffer zones around breeding or migrating Piping Plovers in the Great Lakes region relative to risks associated with wind turbines and infrastructure (Jack Dingledine, U.S. Fish and Wildlife Service, personal communication). Locations of breeding Kirtland's Warblers, Whooping Cranes, and Piping Plovers in the Great Lakes region, which may vary from year-to-year, are available from the East Lansing, Michigan, field office of the U.S. Fish and Wildlife Service; Piping Plover information at Lake of the Woods, Minnesota, is available from the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.

Bald Eagles (*Haliaeetus leucocephalus*) and Golden Eagles (*Aquila chrysaetos*) are protected under the Bald and Golden Eagle Protection Act; Bald Eagles breed, migrate, and winter in the Great Lakes region, while the Golden Eagle is an uncommon migrant regionally that occasionally winters in the Great Lakes region (see McPeek 1994). Both species occur in a variety of habitats (e.g., Great Lakes shorelines, forests, riparian corridors). We suggest that location of wind energy facilities should follow guidelines established by the U.S. Fish and Wildlife Service (2007) but which are being revised in 2011. Adoption of these guidelines should minimize collisions with wind turbines and also minimize potential for displacing breeding birds. For example, construction activity displaced one pair of Bald Eagles within 1,320 ft (400 m) of a turbine location, but the pair established a new nest about 2,970 ft (900 m) from the wind turbine where they successfully raised two young (James 2008).

Direct Mortality

Bird mortalities from collisions with turbines are thought to be low, ranging from <1 bird/turbine/year to approximately 7 birds/turbine/year (Kerlinger et al. 2010) or more (6.99 birds/turbine/6 months at Wolfe Island, Ontario [Stantec 2010]). Compared to collisions with other structures (Erickson et al. 2001) and relative to effects on bats (National Wind Coordinating Collaborative 2010), bird mortality is not likely to have significant effects on most bird populations (National Wind Coordinating Collaborative 2010). Yet, widespread concern about interactions of birds with wind energy development remains. Principal concerns, both short-term and cumulative, include (1) lack of adequate studies to document bird response to wind energy; (2) additional "take" of state and federally listed species, migratory birds, birds of conservation concern, and raptors that migrate along ridgelines or other prominent landforms; (3) mortality or displacement of raptors, especially locally (e.g., Barrios and Rodriguez 2004), and other species that nest close to wind facilities; (4) behavioral and ecological responses of grassland birds and shorebirds to wind turbines; (5) potential for increased bird exposure as turbine numbers and heights increase; and (6) potential for single-night, mass mortality (Manville 2009; see Kerlinger et al. 2010 for a recent review of mass mortality). In addition, there is interest in avoiding areas where high concentrations of birds occur because their associated ascent and descent to and from these areas could place large numbers of birds within the rotor-swept zone (National Wind Coordinating Collaborative 2010).

Approximately 82% of birds colliding with wind turbines outside California are nocturnally migrating passerines (Erickson et al. 2002). Barclay et al. (2007) reviewed the literature and reported the following collision rates: <1 bird/turbine/year (Minnesota agricultural land), 0.63 birds/turbine/yr (Oregon agricultural lands and grasslands), 0-4.45 birds/turbine/yr (mean 2.19 in rangelands, agricultural lands, and woodlands in the United States); 1.5 birds/turbine/yr (Wyoming rangeland); 1.29 birds/turbine/yr (Wisconsin agricultural land and woodlands), and 4.04 birds/turbine/yr (West Virginia forest). The number of collisions of birds with wind turbines does not seem to be different between lighted and unlighted turbines or depend on the type of lighting (Kerlinger et al. 2010).

Raptor collisions with wind turbines are generally low, based on studies from Colorado, Iowa, Montana, Oregon, Tennessee, Vermont, Washington, and Wyoming (Kuvlesky et al. 2007), but mortality has been locally high, as at Altamont Pass Wind Resource Area (APWRA) in California, an early wind energy project, with potentially locally significant effects on populations (Kuvlesky et al. 2007). Raptor mortality has also been reported to be high on Wolf Island, Lake Ontario, Ontario (Stantec 2010). In short, "It appears that raptor collision mortality can be a concern when wind turbines are constructed at inappropriate locations (e.g., migration routes), where large concentrations of raptors occur (e.g., APWRA), or where turbines are constructed in unsuitable locations within a wind farm (R.M. Montes and L.B. Jacques, unpublished report), such as on slopes of hills, draws, or ridges that are frequently used by foraging raptors…" (Kuvlesky et al. 2007).

Collisions of shorebirds and waterfowl with wind turbines are little described in the Great Lakes region but have been noted (Joelle Gehring, Michigan Natural Features Inventory, personal communication). No waterfowl were reported to collide with a 66 wind turbine facility at Erie Shores, Ontario (James 2008).

Displacement, Fragmentation, and Habitat Loss

Displacement of birds due to wind turbines has been reviewed by Drewitt and Langston (2006) and Stewart et al. (2007). Displacement of waterfowl up to 2,640 ft (800 m) from wind facilities have been noted (*in* Drewitt and Langston 2006). Based on a meta-analysis of the literature, Stewart et al. (2007) concluded that the number of turbines had little or no effect on bird abundance, but time since initial operation significantly affected bird abundance, especially for waterfowl and shorebirds. "The fact that longer operating times result in significantly greater declines in abundance than shorter operating times suggests that birds do not become habituated to the presence of windfarms as previously thought likely (Gill et al. 1996; Langston & Pullan 2003), or that local population density declines in spite of habituation. It also indicates that short-term monitoring (2-5 years) is not appropriate for the detection of declines in bird abundance. Furthermore, if this relationship persists, then windfarms could cause larger declines in bird abundance over future decades" (Stewart et al. 2007).

Caveats

Few studies are available regarding particular species' behavioral responses and/or risk of collision from wind energy development. For example, little empirical information is available about how sensitive various endangered/threatened birds like Piping Plover and Kirtland's Warbler might be to disturbance created by turbine construction and operation, which would better inform development buffers for known populations of listed-species. Hence, we recognize that the subsequent spatial recommendation may require modification with additional study.

Similarly, buffers have not been defined for sites where large numbers of migratory birds concentrate (e.g., Important Bird Areas) because of information gaps. Additionally, these areas may harbor congregations of many species, and each species may be differentially sensitive to wind turbines, further complicating our ability to define a buffer around stopover areas. However, once more information is available about angles of ascent and descent to/from staging areas, we anticipate that will facilitate providing recommendations for buffers, which should help abate direct mortality.

Recommendations

Based on the ecological information on birds summarized above, we recommend the following guidelines for the siting of wind turbines.

- Wind turbine development should avoid areas where large numbers of migrating birds concentrate (e.g., Audubon Important Bird Areas), including agricultural fields traditionally used by large numbers of migrating/wintering birds, or where large numbers of migrating birds are predicted to occur (Ewert et al. 2005). Placing wind turbines, or other tall structures, in areas where relatively large numbers of birds occur increases the risk of collision with the structure and may have both local and cumulative consequences for bird populations.
- Sites within 2 miles (3.2 km) of breeding areas of federally endangered, threatened, or candidate endangered animal species (e.g., Piping Plover) and designated habitat for these species (e.g., Kirtland's Warbler) should be avoided.

- Sites near Bald Eagles, including nests, should follow the Draft Eagle Conservation Plan Guidance from U.S. Fish and Wildlife Service (2007a).

C.2. Bats

Introduction

Where possible, we have discussed the threat of bat mortality in relation to the specific ecological systems covered in this document (shorelines, offshore waters, grasslands, forests, inland wetlands, riparian areas, and agricultural lands; Sections IV C.3-9). However, bats are highly vulnerable to turbine-related mortality, perhaps because they travel widely, migrate great distances, and may be attracted to turbines (Kunz et al. 2007b). Direct mortality is likely to be the greatest threat to bat populations because bats are long-lived species whose populations are particularly dependent upon relatively low adult mortality (Schorcht et al. 2009). Bats may be particularly vulnerable to direct mortality for two reasons. First, they may be attracted to turbines from a distance (Kunz et al. 2007b, Cryan and Barclay 2009, National Wind Coordinating Collaborative 2010). Second, bats that do not directly impact turbine blades may still be killed by barotrauma, an internal injury caused by sudden changes in air pressure near moving blades (Baerwald et al. 2008). Finally, bats appear to be highly vulnerable to white-nose syndrome (Burton 2009) in addition to interactions with wind turbines. Bats help control populations of crop pests, providing an ecosystem service valued at more than $3.7 billion/year (Boyles et al. 2011). These factors underscore the need to be especially cautious about bat-wind turbine interactions.

Direct Mortality

In the United States, one group of bats commonly referred to as migratory tree-bats (including hoary bats [*Lasiurus cinereus*], red bats [*Lasiurus borealis*], and silver-haired bats [*Lasioycteris noctivagans*]) are most often killed at turbines, especially during the fall migration from July-September (Arnett et al. 2008). This suggests that this group of bats is most vulnerable during migration, perhaps because of some behavior specific to migration. However, the spatial distribution of bat migration is not known, so our understanding of the spatial extent of this threat of bat mortality is incomplete. It is not yet known whether bats use consistent migratory routes, and if so where these routes might be (Section V). Furthermore, it is not known whether bats are vulnerable while actively migrating across the landscape or whether they migrate above the height of turbines and are vulnerable only when ascending, descending, or foraging near stopover locations. Bat mortality appears to be greatest (up to 70/turbine) at turbines on forested ridges in the eastern U.S. (Arnett et al. 2008). One tentative explanation for this pattern of greater mortality along forested ridges is that bats may migrate along linear landscape features such as ridges, coastlines, tree rows, and rivers (Baerwald and Barclay 2009, Cryan and Barclay 2009, Furmankiewicz and Kucharska 2009). However, this hypothesis has not yet been adequately tested. On the other hand, bats may migrate in a broad front, similar to songbirds, irrespective of the landscape features below them. For these reasons, it is difficult to discuss turbine-related bat mortality within specific ecological systems.

Although most mortality occurs among migratory tree bats during the fall migration, substantial mortality of other species (big brown bat [*Myotis lucifugus*] and little brown bats [*Eptesicus fuscus*]) has also been reported in some sites near hibernacula. Many species that use hibernacula "swarm" there in the fall, roosting in trees and foraging in high densities nearby from mid-July until mid-September (Thomas et al. 1979) or mid-October (U.S. Fish and Wildlife Service 2007b). This concentration of large numbers of bats within 0.2-37.2 miles (0.3-60 km) of the hibernaculum (U.S. Fish and Wildlife Service 2007b) would be at risk of direct mortality if turbines were sited nearby. At three wind energy facilities within 30 miles (50 km) of the Neda Mine, Wisconsin, a regionally important hibernaculum hosting about 200,000 individuals, mostly little brown bats (University of Wisconsin Milwaukee), surprisingly large numbers of little and big brown bats were found dead (Gruver et al. 2009, BHE Environmental Inc. 2010, Drake et al. 2010). Because these species are less frequently struck by turbines at other sites (Kunz et al. 2007b), Gruver et al. (2009) suggest that proximity to this large hibernaculum increased the risk to these species, although the wind energy facilities are in a primarily agricultural landscape. Thus, even though the hibernaculum is in a forested area, the spatial extent of its impact on bat mortality risk may extend far outside the forest system.

Estimating the spatial extent of bat population concentrations around hibernacula is difficult. Except for the relatively intensively-studied Indiana bat (*Myotis sodalis*), little is known about bat movement between hibernacula and summer colonies. Most of the 105 Indiana bats radio tracked with aircraft in New York traveled less than 40.3 miles (65 km) from hibernacula to summer colonies (U.S. Fish and Wildlife Service 2007b; Al Hicks, New York State Department of Environmental Conservation, personal communication). However, distances migrated may vary substantially across the Great Lakes region. In Pennsylvania, five female Indiana bats traveled 45.9-87.4 miles (74-141 km) between hibernacula and summer colonies (Butchkoski and Turner 2008). Four Indiana bats with summer colonies in Michigan migrated an average of 285.2 miles (460 km) (up to 329.8 miles [532 km]) to hibernacula in Indiana and Kentucky (Kurta and Murray 2002). Eight Indiana bats banded in Ohio from 2008-2010 were found 92-124 miles (153-207 km) away in Kentucky (Keith Lott, U.S. Fish and Wildlife Service, personal communication). Little brown bats may also travel long distances from hibernacula to summer colonies, up to 217 miles (350 km), but other species may migrate shorter distances (Kurta 1995). This aspect of bat biology also complicates a spatial understanding of turbine-related mortality risk to bats.

Caveats

Bat hibernacula are sensitive to development, but this sensitivity and risk for collision, particularly as a function of distance from essential habitats and migratory corridors, is poorly understood. New York (New York State Department of Environmental Conservation 2009), Ohio (Ohio Department of Natural Resources 2009), and Pennsylvania (Pennsylvania Game Commission 2007), suggest that potential development sites within 25, 5, and 5 miles (40, 8, and 8 km, respectively) of hibernacula are particularly sensitive and recommend intensive study before development should proceed. Ontario recommends additional study and mitigation plans if development occurs within 396 ft (120 m) of the edge of significant wildlife habitat, which includes bat hibernacula, maternity colonies, wetlands, and forested ridges, among other features (Ontario Ministry of Natural Resources 2010). Wisconsin also recommends avoiding potential development sites near bat hibernacula and staging areas (Wisconsin Department of Natural Resources 2004), and Michigan recommends additional study when potential development sites are near wildlife refuges or bat hibernacula (Michigan Department of Labor and Economic Growth Energy Office 2007), but they did not recommend specific buffer sizes around bat habitat. We agree that further study is necessary to determine the safety of turbine construction near hibernacula and that we cannot currently articulate quantitative buffer distances around hibernacula without further study.

Recommendations

Because of the reasons discussed above, including uncertainty and very large buffer sizes around critical bat habitat features, we cannot rely on spatial guidelines to decrease bat mortality risks posed by wind energy development. In contrast, operational mitigation has been shown to dramatically reduce mortality.

- We recommend operational guidelines to reduce bat mortality (described in Section IV C.10).

C.3. Great Lakes Open Waters: Nearshore and Offshore

Introduction

The Laurentian Great Lakes basin ecosystem includes open lake (nearshore and offshore waters); connecting channels; wetlands (including coastal and inland wetlands); tributaries; coastal shores; beaches and dunes; rare lakeplain communities (i.e., prairies and savannas); and terrestrial inland systems. Of these, the open waters represent some of the greatest wind resources (see AWS Truewind 2008 and others). The potential extent of wind development could be vast, since Great Lakes open waters have a combined surface area of about 95,160 mi^2 (244,000 km^2) (The Nature Conservancy 1994, Franks Taylor et al. 2010). These aquatic systems are some of the world's most important freshwater habitats and water resources (The Nature Conservancy 1994). Although Edsall and Charlton (1997) defined nearshore waters as a band of varying width (33 ft-100 ft [10-30 m]) around the perimeter of each lake, between the shoreline and deeper offshore water, we elected to follow Mackey (2009a) and define the nearshore zone as water depth up to 50 ft (15 m) which includes "higher energy *coastal margin* areas and lower energy *nearshore open-water* areas" (Mackey 2009b).

Because species potentially sensitive to development occur both nearshore and offshore, and there are seasonal differences in their distribution, siting recommendations for nearshore and offshore areas are combined here. Species that may be sensitive to wind energy development include migratory birds (landbirds, waterfowl, shorebirds, and other waterbirds), fish, mussels, and other invertebrates. Benthic communities could also be affected by wind turbine development.

The erection of offshore wind turbines may affect migratory birds and bats in five ways: (1) risk of collision, and for bats barotrauma, i.e., direct mortality; (2) long-term habitat loss (air space, surface water area, and subsurface water) due to disturbance by the turbines including disruption from boating activities associated with maintenance; (3) fragmentation due to barriers within migration routes; (4) displacement behaviors associated with disruption of ecological routes, such as those used between roosting, nesting, and feeding sites and (5) short-term habitat loss during construction (modified from Exo et al. 2003). Of these five risks, disturbance and barrier effects may constitute the highest conflict potential for birds (Exo et al. 2003). Little is known about bat displacement or avoidance behavior (Section V). Direct mortality and habitat fragmentation, might also negatively impact nearshore and offshore fish communities, although this has not been well studied (see Engel-Sorensen and Skyt 2001, for example).

Cumulative effects of these potential risks are not understood, and the potential for direct mortality, particularly as a function of distance from coastal areas and islands, has not been researched (Section V). Even though areas where birds concentrate seasonally have been described, and research is beginning to focus on bat migratory routes, the specific timing, routes, and altitudes that migrants use are poorly known, and such information is needed to conduct assessments of potential risks from the conflicts listed above (Arnett et al. 2007). Cumulative effects on other taxa such as fish or benthic communities are not known (Section V).

Studies of avian distribution on the open waters of the Great Lakes are very few. Stapanian and Waite (2003) counted birds along 31 transects in four habitats of western Lake Erie within 7.4 miles (12 km) of the shoreline: offshore wildlife refuges, offshore beaches with development, reefs and shoals, and open water. They found more birds nearshore than offshore, in contrast to Langen et al. (2005), who found no differences in number of birds or species richness on Lake Ontario as a function of distance from the shoreline. Lott et al. (2011) found that the vast majority of birds in the Ohio portion of Lake Erie were within 2.5 miles (4.1 km) of the shoreline, based on aerial surveys during spring and fall migration, but birds were also found in the middle of Lake Erie. Surveys conducted in Canadian waters of Lake Erie indicate most waterfowl occur within 3 miles (5 km) of the shore during the day (Scott Petrie, Long Point Waterfowl, personal communication).

No offshore wind developments have been constructed yet in North America, so impacts to fish and wildlife resources are unknown. Some pre-construction data collection has begun in the Great Lakes region and along the Atlantic coast in anticipation of wind project development, and in some cases species or guild-specific risk analyses have been conducted. In Europe, where offshore marine wind power is most prevalent, only limited post-construction monitoring has been completed to document effects of offshore wind projects on fish, wildlife, and aquatic resources. Additionally, most existing literature addresses impacts on migratory birds and not other biota that might be sensitive to development, e.g., bats, fish, and benthic communities. However, here we attempt to highlight those data which may be applicable to the Great Lakes region and expand concerns to fish, benthic communities, and ecological processes.

Direct Mortality: Birds

The number of migratory bird collisions with offshore wind turbines may be smaller than mortality estimates from other structures (U.S. Fish and Wildlife Service 2002). However, there have been concerns about the adequacy of post-construction research on bird kills at offshore turbines. Even though more than 280 studies have been conducted relating environmental and human effects from offshore wind installations in Europe, most projects had fewer than 10 turbines and were not rigorously designed or peer-reviewed (Arnett et al. 2007). Quantitative assessments of collision risk at offshore turbines are difficult to obtain since they are highly site-dependent, inadequate data exist on bird migration routes and flight behavior (Exo et al. 2003), risk level may vary for different offshore species, measurements are based on found bird corpses, and results have been variable among studies (Desholm and Kahlert 2005).

However, for some types of birds, the risk of turbine-associated direct mortality can be high. Perhaps the first projects studying ecological effects of wind energy in offshore, nearshore, and tidal areas began with Winkelman's work in The Netherlands (Winkelman 1989, 1992a-d, 1994, 1995). Winkelman (1994) found 303 dead birds (which included waterbird and landbird species) at 108 sites, of which at least 41% died as a result of collision with wind turbines. One important conclusion of his studies was that collision risks are highest during dark nights and nights with bad weather.

Although some papers, like Winkelman's, cite mortality of landbird species, a thorough risk assessment for this assemblage has not been undertaken. Compared to any other group of migratory birds, landbirds may be at the highest risk of collision. Landbirds are a highly diverse group of species, typically migrate in broad fronts, and may experience higher mortality during migration compared to their breeding and wintering grounds (Sillett and Holmes 2002). Further, the majority of landbird species migrate nocturnally (Farnsworth et al. 2004), which might increase risk of collision. However, little information exists regarding landbird flight patterns and height of migration as a function of distance from the shoreline (see Section IV C.1).

Dirksen et al. (2000) provide a review of Dutch research on the risk of mortality, focusing mainly on nocturnal flight movements and altitudes of ducks and shorebirds in open seascapes without wind turbines, along with the reactions of diving-ducks passing a nearshore wind energy facility when flying to and from their nocturnal feeding areas. They showed that daily diurnal and nocturnal flights of shorebirds in tidal areas and diving ducks in offshore areas were usually below 330 ft (100 m), which is within the rotor-swept area of present wind turbine designs, and thus could be at risk of collision in these areas. Species observed migrating during darkness included Black-bellied Plover (*Pluvialis squatarola*), Red Knot (*Calidris canutus*), and Dunlin (*Calidris alpina*), all of which migrate regularly through the Great Lakes; Black-bellied Plover and Red Knot occur most commonly near the Great Lakes compared to inland areas (McPeek 1994, Anderson et al. 2002). The two species of ducks found to fly at night, Tufted Ducks (*Aythya fuligula*) and Pochard (*Aythya ferina*), are Old World species. Common Goldeneye (*Bucephala clangula*), Greater Scaup (*A. marila*), and Red-breasted Merganser (*Mergus serrator*), all of which commonly occur in the Great Lakes, migrated diurnally or during dusk and dawn. Hüppop et al. (2006) monitored year-round migration from a research platform in the Baltic Sea and found that half of the migrating birds fly at altitudes within rotor-swept areas of turbines. The authors also demonstrated that under poor visibility, terrestrial birds are attracted to illuminated offshore obstacles, and this, when combined with the common phenomena of reverse migration (e.g., flight in the direction opposite the ultimate destination), risk of collision for passerines would be increased. The authors suggested that on a few nights per year, a large number of avian interactions at offshore plants can be expected. Along with making wind turbines more recognizable to birds (e.g., intermittent lighting), the authors suggest that wind developments in zones with dense migration should be abandoned, and they advocate turning off turbines at night when there is both adverse weather and predicted high migration events.

Risk of direct mortality seems to vary among different types of birds. At the Nysted and Horns Rev offshore wind developments in Denmark, waterfowl and waterbird species may be at relatively low collision risk, since these species often exhibit avoidance responses to turbines (Petersen et al. 2006). Petersen et al. (2006) modeled collision risk for Common Eider (*Somateria mollissima*), a ubiquitous waterfowl species near the Nysted and Horns Rev offshore wind developments, and predicted that of 235,000 passing birds, approximately 41-48 individuals would collide with the turbines in a single autumn. In southern Kalmar Sound, Sweden, a flock of about 310 Common Eider flew within 330 ft (100 m) from the northernmost wind turbine at Yttre Stengrund, and the outer flank of the flock was struck by the rotor (Pettersson 2005). Four birds fell into the water and three of these were observed flying quickly away from the area, while one bird was probably killed. In addition, five near-accidents were observed when flocks swerved to one side or turned sharply near the turbines in order to avoid a collision. He calculated the collision risk to be one bird per year per wind turbine in Kalmar Sound. Given this low rate, direct mortality at this site likely has little effect on regional Common Eider populations. However, about 30% of the waterfowl that migrate through the sound were impacted by the turbines at Utgrunden and Yttre, mostly through avoidance behavior created by habitat loss and migration barriers (see subsections below). Research by Desholm and Kahlert (2005) at the Nysted wind development in the Baltic Sea corroborates the relatively low collision risks for waterfowl; overall, less than 1% of the ducks and geese tracked by radar migrated close enough to the turbines to be at risk of collision.

Everaert and Stienen (2007) studied the impacts of wind turbines on birds on Zeebrugge, Belgium, near a breeding colony of Common Terns (*Sterna hirundo*), Sandwich Terns (*Thalasseus sandvicensis*), and Least Terns (*Sternula antillarum*). The mean number of terns killed in 2004 and 2005 was 6.7 per turbine per year for the entire development, and 11.2 and 10.8 per turbine per year, respectively, for the line of 14 turbines on the sea-directed breakwater immediately adjacent to the colony. The researchers recommended avoiding the construction of wind turbines close to any important breeding colony of terns or gulls, and avoiding development within frequent foraging flight paths, although precise buffers were not defined.

Garthe and Hüppop (2004) developed a wind energy facility sensitivity index (WSI) for waterbirds and waterfowl in the North Sea. The index combined nine factors, derived from species' attributes: flight maneuverability; flight altitude; percentage of time flying; nocturnal flight activity; sensitivity towards disturbance by ship and helicopter traffic; flexibility in habitat use; bio-geographical population size; adult survival rate; and European threat and conservations status. These metrics were meant to evaluate mortality risk and potential effects from habitat loss and migratory barriers (see below for more information on the latter two components). Analyzed species differed greatly in their sensitivity index, but Arctic Loon (*Gavia arctica*) and Red-throated Loon (*Gavia stellata*) were ranked as the most sensitive to wind energy development, followed by White-winged Scoter (*Melanitta fusca*), Sandwich Tern, and Great Cormorant (*Phalacrocorax carbo*). The lowest sensitivity values were recorded for Black-legged Kittiwake (*Rissa tridactyla*), Black-headed Gull (*Larus ridibundus*), and Northern Fulmar (*Fulmarus glacialis*). Of these, both Red-throated Loon and White-winged Scoter occur regularly in Great Lakes waters. Given the sensitivity of the two loon species, impacts on Common Loon (*Gavia immer*), which is an abundant migrant over the Great Lakes, might also be an important consideration when siting wind energy projects.

Possible risk of collision for other Great Lakes waterfowl, including Canvasback (*Aythya valisineria*), Redhead (*Aythya americana*), Lesser Scaup (*Aythya affinis*), scoters, and Long-tailed Duck (*Clangula hyemalis*), is not well understood. At least some of these species, Canvasback, Redhead, and Lesser Scaup, are concentrated in nearshore waters while other species, Long-tailed Duck and scoters, may forage and concentrate in offshore waters of the Great Lakes (McPeek 1994). Studies have recently been initiated in Lakes St. Clair, Michigan, Ontario, and Erie to better describe the distribution of these species on the Great Lakes.

<u>Direct Mortality: Bats</u>

No bat fatality data are available for offshore turbines because of the difficulty of finding carcasses. However, even turbines far from land may be a threat, because bats are known to migrate across open water. During migration, hoary bats are routinely found stopping over on Southeast Farallon Island, 19 miles (32 km) from the coast of California (Cryan and Brown 2007). Eastern red, hoary, and silver-haired bats also migrate along a barrier island (Assateague Island) off the coast of Maryland (Johnson et al. 2011). Several species of European bats were detected at least 9 miles (14 km) from shore while migrating across the Baltic Sea (Ahlen et al. 2009), and several records exist of red and silver-haired bats found upon ships up to 149 miles (240 km) from land (e.g., Mackiewicz and Backus 1956). An estimated 100 silver-haired, hoary, red, and Seminole bats migrate through Bermuda each fall (Van Gelder and Wingate 1961). Therefore, offshore turbines present a threat to migratory bats, but this threat has not been quantified.

Direct Mortality: Fish and Benthic Communities

Although poorly studied, offshore wind energy developments may also create mortality risks for fish communities, particularly from disturbed sediments caused by turbine construction. The effect of fine sediment particles (silt) is especially negative for the larvae, because they adhere to the gills and cause suffocation (de Groot 1980 *in* Engell-Soresen and Skyt 2001). Sediment concentrations in the range of milligrams per liter can be lethal for eggs and larvae, while for juveniles and adults this effect is not to be expected below concentrations of grams per liter (Engell-Soresen and Skyt 2001). At the Danish Nysted offshore wind development, Engel-Soresen and Skyt (2001) found that pelagic eggs and larvae surrounding the turbine foundations would be negatively impacted by sediment loads during construction, thereby decreasing productivity and recruitment rates in pelagic fish species. Larvae and eggs laid on the sea or lake bed would also be affected; however, compared to pelagic species, they can tolerate higher sediment suspension rates, so smaller negative effects are to be expected. The duration of high suspension rates and subsequent impacts are poorly known. Invasive species, such as gobies and dreissend mussels, might concentrate near foundations of turbines resulting in adverse effects on fish and other members of the benthic community (Scott Petrie, Long Point Waterfowl, personal communication).

Construction of offshore wind turbines in the Great Lakes will also likely necessitate laying more underground cables for transmission, and, although poorly studied, this may have negative consequences on benthic communities. Söker et al. (2000) estimated that cable laying may disturb a 6.6 ft (2 m) wide sector on the ground on both sides, and water will be disturbed some meters around the construction site. The authors expect the effects on water flow to be diminished after some hours, whereas disturbance to the sea floor would be observable for some weeks. However, Söker does not offer any temporally or spatially-explicit estimates for what 'some meters', 'some hours', and 'some weeks' encompass. These numbers are likely dependent on the type of substrate and amount of convection in the waters. Söker also suggests that benthic flora and fauna in a wider range than the 6.6 ft (2 m) sector will be covered with mud and sand, and their mechanisms of filtration could be at least temporarily obstructed. Possible turbidity of the seawater could affect the growth of the macrobenthos (e.g., mussels) for a certain period, while also having a lethal effect on some species.

Habitat Loss and Barrier Effects: Birds

Birds may also be affected by short- and long-term habitat loss, fragmentation, and behavioral responses such as avoidance. Although avoidance and displacement may reduce direct mortality risk, these behaviors indicate that wind energy facilities can cause habitat loss and cause barriers to migration. Such losses should be assessed in terms of the potential feeding habitat affected, relative to areas outside of the wind energy facility. For instance, if turbines are built in offshore western Lake Erie, their construction and operation could force island nesting waterbirds to adjust routes to coastal feeding areas during the breeding season and impose a barrier during migration. Although avoidance of turbines may diminish risk for direct mortality, how will adjusted migratory routes and flight paths to/from critical foraging areas, or the potential to lose high quality foraging sites, and the potential bio-energetic demands for such extended modifications, impact population viability? Measurement of these cumulative effects is a high priority when considering the future effects of developments along an avian flyway. Some research has been done to determine mortality rates for long distance migrants throughout their life cycle (see Sillett and Holmes 2002), but the relative contributions of collisions, predation, barrier effects, or habitat loss to mortality rates remain unknown.

Petersen et al. (2006) monitored birds during 1999-2005, related to the construction of the world's first large offshore wind energy facilities at Horns Rev and Nysted in Denmark. Results showed that birds generally avoided both developments, although responses were highly species specific. Some species (e.g., loons and gannets) were almost never seen flying between turbines, others rarely (e.g., White-winged Scoter), while still others showed little to no avoidance behavior (e.g. cormorants and gulls). However, at Horns Rev, 71-86% of all bird flocks heading for the wind energy facility at 0.9-1.2 miles (1.5-2 km) distance avoided entering the area. Further, the numbers of Common Eider entering the Nysted wind energy facility decreased by 63-83% post construction, and that proportions of birds crossing the wind energy facility area have decreased relative to the pre-construction baseline (see Fox et al. 2006). Radar studies provided evidence that many bird species showed avoidance responses at distances of up to 3.7 miles (5 km) from the turbines, and within a range of 0.6-1.2 miles (1-2 km), that more than 50% of birds heading for the wind energy facility avoided passing within it (Petersen et al. 2006). No bird species demonstrated enhanced use of the waters (Petersen et al. 2006).

Pettersson (2005) found analogous avoidance and displacement behaviors for bird life at offshore wind energy facilities in southern Kalmar Sound, Sweden. His four years of research showed that about 30% of the waterfowl that migrate through Kalmar Sound were affected to some extent by the wind energy facilities at Utgrunden and Yttre Stengrund. Although no significant change was shown for autumn passage, the Utgrunden wind project displaced the migration corridor for spring migrating Common Eider eastward towards the coast of Öland. Other species showed fewer barrier effects – approaching birds would generally start an evasive maneuver 0.6-1.2 miles (1-2 km) before entering the wind energy facilities. Pettersson estimated that birds exhibiting this tactic extended their migration distance and time by 0.2-0.5%, which represented only marginal increase expenditures for the entire migration pathway. However, Utgrunden is still used by staging and wintering waterfowl, including the Long-tailed Duck. It is unclear if increased energy expenditures due to avoidance occur with higher concentrations of wind energy structures than those at Utgrunden (Scott Petrie, Long Point Waterfowl, personal communication).

Petersen et al. (2006) also investigated the effects of maintenance activities on bird use of wind energy facilities in Denmark. Long-tailed Ducks and Red-breasted Mergansers were displaced by service boats operating in the wind energy facility. Birds were found not to return to their foraging sites until 21-30 minutes after the service boat left the area. Possible effects on energetic budgets for this disturbance time were not described. Common Scoter, Common Eider, Long-tailed Duck, Common Tern, and Arctic Tern (*Sterna paradisaea*) all demonstrated avoidance of the wind energy facility during construction and operation phases. Of these species, Common Scoter, Red-breasted Merganser, Long-tailed Duck, and Common Tern frequent Great Lakes offshore areas during migration (Soulliere et al. 2007). Pettersson (2005) concluded that boats servicing the wind turbines Kalmar Sound, Sweden, were a greater source of disturbance to birds than the wind turbines themselves.

Habitat Loss and Barrier Effects: Fish and Benthic Communities

The cumulative effects of wind turbine construction, especially with regard to habitat loss and displacement, on fish communities are poorly studied and understood (see Wilhelmsson et al. 2010). Smith and Westerberg (2003) suggest that the submerged structure of an offshore wind turbine could be considered an artificial reef, and thus create more spawning and nursery habitats for pelagic fishes. However, the disturbance from construction can have possible recruitment effects for predators, resulting in increased predation on prey species' productivity.

Caveats

The buffer recommended below is derived from initial results of Lott et al. (2011) and Cooper et al. (2004), the latter of which was, in part, a terrestrial vertical radar study conducted for the proposed Chautauqua wind energy facility. Data from a radar station located 3.7 miles (6 km) south of Lake Erie indicated that the mean percentage of nocturnal migrants flying 3.3-412 ft (1-125 m) above ground level was 4% in the fall and 3.8% in spring. Three major caveats must be cited here: (1) this was a terrestrial study, so whether these flight heights can be applied at the same distance from the shoreline above the lake is not known; (2) how birds would interact with the development and the potential number of collisions with the turbine blades are unknown; and (3) the species that would be most affected are unknown. Although Cooper's study was positioned 3.7 miles from the shoreline, we extrapolated this distance to 5 miles (8 km) to accommodate for the larger offshore wind turbine height and rotor swept area, which can reach 440 ft (134 m) above the water's surface (Casey and Roche 2008) and at least 30 ft (9 m) higher into the wind column than most terrestrial turbines. As more tracking radar and vertical radar studies are conducted (Section V), the 5 mile (8 km) buffer will be refined, and perhaps adjusted for different parts of the Great Lakes' basin.

Cross-lake migratory routes are poorly known for birds and especially bats. Migratory birds are reported to follow the islands between Ohio and Ontario during migration and islands between the Garden and Stonington peninsulas, Michigan and Door County, Wisconsin Similar pathways may exist elsewhere in the Great Lakes but this requires further evaluation.

Data from current and planned pelagic bird surveys within the Great Lakes should help define offshore Important Bird Areas and other concentration areas. Since most birds resting and foraging in offshore zones, like waterfowl and waterbirds, typically exhibit avoidance behavior and are not as prone to collision, construction buffers around IBAs may not be necessary. However, this assumption needs to be tested since the cumulative effects of avoidance on fitness are not well understood.

Protocols to identify and categorize important fisheries have not been developed, so the term 'important' in this recommendation is still subjective and needs refinement. Walleye (*Sander vitreus*), lake trout (*Salvelinus namaycush*), and lake herring (*Coregonus artedi*) are likely a few species that breed in nearshore/offshore waters (Hubbs and Lagler 1964), so particular attention may be warranted for these taxa, among others. Since turbine foundations, if correctly constructed and enhanced with sub-aquatic vegetation, may provide additional habitat for such species (Smith and Westerberg 2003), this recommendation might be better focused on disturbance created by burial of underground transmission.

Recommendations

Although recommended buffers will be refined with more research in the Great Lakes, the following places should be avoided in development:

- Avoid offshore areas within 5 miles (8 km) of the nearest coast or shoreline, including those for both the mainland and islands.
- Avoid placement of turbines on known or suspected cross-lake migratory routes of birds and bats on peninsulas or chains of islands (e.g., Sandusky Bay to Point Pelee, Presque Isle to Long Point, Huron-Erie, and other corridors such as the Garden Peninsula, Michigan to Door County, Wisconsin corridor).
- Avoid offshore Audubon Important Bird Areas (IBAs), either potential or recognized, and waterbird/waterfowl refuges, i.e., those areas in which at least 1% of the region's population of a species resides during breeding and/or non-breeding times (National Audubon Society 2010).
- Avoid important spawning and nursery habitat for fish communities (e.g., walleye and perch shoals in western Lake Erie).

C.4. Great Lakes Coastal Zone, Terrestrial Shorelines, and Islands

Introduction

The Great Lakes coasts and shorelines include wetlands, drowned river mouths, shallow water habitats, oak savannas, upland forests, beaches, and dunes, among others. These coastal ecosystems offer diverse habitats that support a myriad of plant, fish, and wildlife species. The basin's islands contain virtually all the unique natural features associated with the Great Lakes shoreline (Henson et al. 2010), some of the last intact ecological communities found in the Great Lakes, and the vast majority of the regions' nesting colonial waterbirds, and are thus included within this section.

Areas within the shoreline and coastal zones are the most diverse and productive areas of the Great Lakes (Mayer et al 2004; Maynard and Wilcox 1997). These ecosystems include the relatively warm and shallow waters near the shore, approximately 300,000 acres (118,110 ha) of coastal wetlands (Herendorf et al. 1981). Great Lakes wetlands play a pivotal role in the Laurentian aquatic ecosystem by storing and cycling nutrients and organic material from the land into the aquatic food web. Coastal wetlands have a unique position in the landscape as they intercept, transform, and accumulate chemical, nutrient, and sediment inputs that flow from upland areas toward nearshore and offshore open waters.

Coastal wetlands. Great Lakes coastal wetlands support many species and plant communities of conservation concern, concentrations of migrating birds and perhaps bats, and critical processes that maintain these species and communities. The aquatic plant communities are among the most biologically diverse and productive freshwater systems in the world (Maynard and Wilcox 1997). For many migratory waterfowl and shorebirds, these wetland systems are a critical part of the life cycle (Potter et al. 2007, Soulliere et al. 2007). Amphibians and invertebrates depend on coastal wetlands for their population recruitment and viability (Price et al. 2005). Wetlands also play an essential role in sustaining fish populations, with many species of Great Lakes fish depending on coastal wetlands for successful reproduction (Jude and Pappas 1992; Krieger 1992).

Coastal uplands. Many upland and terrestrial communities comprise Great Lakes shorelines, including sand dunes and beaches, lakeplain prairies, and coastal upland forests. Great Lakes coastal dunes, the most extensive freshwater dune system in the world, contain numerous rare species, and are heavily influenced by wind and water level fluctuations of the Great Lakes (Peterson and Dersch 1981; Lichter 1998).

Great Lakes islands. The Great Lakes shoreline system encompasses over 32,000 islands, which represents the largest freshwater island system in the world (Henson et al. 2010). The islands contain significant biodiversity including endemic species, rare habitats and critical biological functions. They are important breeding and staging areas for colonial nesting waterbirds, harbor noteworthy assemblages of plants and animals, and provide important stopover sites for migrating birds (Henson et al. 2010). Overall, the islands make a significant contribution to the physical and biological diversity of the Great Lakes and surrounding basin (Vigmostad et al. 2007).

Migrating insects. Dragonflies have been seen flying over Lake Erie from Point Pelee, Ontario, and over 100,000 dragonflies have been observed migrating within 0.75 miles (1.25 km) inland from the north shore of Lake Erie at a single location in a 3 hour period (Nisbet 1960). In Chicago, over 1.2 million dragonflies were estimated to fly within 2,376 ft (720 m) of the Lake Michigan shoreline, mostly at heights <181.5 ft (55 m), during a 5 hour period in September (Russell et al 1998). Russell et al. (1998) cited other examples of dragonfly migration in the Great Lakes region. These observations suggest that at least areas close to the Great Lakes may be major migration corridors for dragonflies, but much remains to be evaluated.

Migrating birds: shorebirds. The Western Hemisphere Shorebird Reserve Network has identified the marshes of the western Lake Erie basin in Ohio and Michigan as being regionally important: >20,000 shorebirds use this area during any given migration season, and 38 species of shorebird have been documented using these areas. Wetlands more than 25 acres (10 ha) within 10 miles (16 km) of the western Lake Erie shoreline were considered to be most important as shorebird stopover sites (Ewert et al. 2005). In this part of the Great Lakes basin, shorebirds use both inland wetlands and Lake Erie shorelines, especially estuaries and managed marshes. The tip of the Garden Peninsula, Michigan (Skye Haas, personal communication), and other peninsulas with fringing low gradient bathyometric slopes, are likely important shorebird stopover sites but more surveys are needed to estimate the number of shorebird using these areas.

Migrating birds: landbirds: songbirds. As with other large bodies of water, the shorelines of the Great Lakes provide landfall for birds migrating over the Great Lakes (Diehl et al. 2003). Landfall effects may be enhanced during adverse weather. Studies conducted throughout the Great Lakes basin (Bonter et al. 2009) and near Lakes Huron (Ewert and Hamas 1996, Smith et al. 1998, Smith et al. 2007, Ewert et al., in press), Erie (Rodewald 2007, MacDade 2009), Ontario (Agard and Spellman 1994), Michigan (Feucht 2003), and Superior (Johansen et al., no date, Anna Peterson, University of Minnesota, personal communication) suggest there may be a "shoreline effect," areas where landbirds concentrate, that is at least 0.6-6 miles (1.0-10 km) inland from the shoreline and large numbers of landbirds may be within 50 m of the canopy three or more miles inland (Anna Peterson, University of Minnesota, personal communication). There may be a rapid decrease in numbers of birds with increasing distance from the shoreline; significant declines in numbers of birds have been detected at 0.25 mile (0.4 km) (Ewert et al., in press) to 0.6 mile (1 km) (Johansen et al., no date) to 1.2-1.8 miles (2-3 km) from the shoreline (Agard and Spellman 1994). Migrants typically gain mass along the immediate shorelines of Lake Huron (Smith et al. 2007), Lake Ontario (Bonter et al. 2007), and Lake Erie (Dunn 2000, 2001), suggesting that most shoreline areas provide adequate food resources for most species (but see Dunn 2000). Migrants may also be relatively abundant near wetlands close to the shoreline along Lakes Michigan (Grveles 1998, Hyde 1998), Superior (Johansen et al., no date), and Huron (Hazzard 2001), and perhaps more generally.

The frequency with which migrants concentrate near the shoreline may vary with shoreline features, including the cardinal direction of the shoreline, the productivity of the immediate shoreline relative to other shoreline and more inland sites (Dunn 2001, Smith et al. 2007; Bonter et al. 2007), and other factors. Using a variety of techniques, studies indicate that peninsulas might have relatively high concentrations of migrants (Johansen et al., no date) and that the abundance of migrants along Great Lakes shorelines may vary with attributes of these shorelines. Based on NEXRAD studies, concentration areas for migrants in the Great Lakes region had 1.2 times more forest cover and 9.3 times more water cover than areas with relatively few migrants (Bonter et al. 2009). Consequently, wetlands, perhaps especially wooded wetlands close to the Great Lakes shorelines, may be disproportionately used by migrating landbirds.

Migrating birds: raptors. Large numbers of raptors migrate along or near the Great Lakes shorelines (Bildstein 2006, Goodrich and Smith 2008, Seeland 2010). During spring migration, hawks and owls tend to accumulate along the southern shores of the Great Lakes, especially at places like Whitefish Point (Michigan) and Derby Hill (New York), while large numbers of birds follow the northern shores of the lakes (Duluth, Minnesota; mouth of the Detroit River, Ontario) during fall migration. More than 500,000 Broad-winged Hawks (*Buteo platypterus*) have crossed the mouth of the Detroit River in one day during fall migration (Panko and Battaly 2010). Large numbers of raptors also occur along inland ridges elsewhere and along major rivers, such as the Mississippi and Iowa Rivers (Goodrich and Smith 2008). Though incompletely documented, at least some raptors fly at heights swept by rotating blades of wind turbines; the proportion of migrating raptors flying at heights swept by the blades varies by species, weather, and site along the Lake Superior shore of Minnesota (Seeland 2010), and probably elsewhere.

Colonial nesting waterbirds. Shoreline wind development may also affect colonial nesting waterbirds (e.g., gulls, terns, herons, and egrets), at least locally. The distribution and prioritization of nesting waterbirds, including loons, grebes, and rails, and colonies of pelicans, cormorants, gulls, terns, and herons, on Great Lakes islands and immediate coastline, is summarized in Wires et al. (2010). Many of these species nest primarily on islands; some islands in the Great Lakes are especially important sites for globally significant populations of such species (Wires et al. 2010). For example, 80-94% of the world's breeding population of Ring-billed Gulls (*Larus delawarensis*) and perhaps as much as 28% of the world's population of breeding Double-crested Cormorants (*Phalacrocorax auritus*) occur in the Great Lakes (Vigmostad et al. 2007), mostly on islands. Additionally, as many as 60% of the North American population of breeding Herring Gulls (*Larus argentatus*) nest in the Great Lakes, mostly on islands (Vigmostad et al. 2007). For other species, including Common Tern (*Sterna hirundo*) and Caspian Tern (*Sterna caspia*), Great Lakes islands support nearly all the regional breeding populations. West Sister Island (Lake Erie) was used for nesting by eight waterbird species in the late 1990s (Wires and Cuthbert 2001). The islands provide refuge from mammalian and avian predators due to their isolation. Because some species of waterbirds collide with turbines (Everaert and Stienen 2007), wind energy facilities should not be placed on or near islands with breeding colonies, especially those sites that consistently support large numbers of nesting waterbirds (see Wires et al. 2010).

Bats. In the Great Lakes region, migrating bats may concentrate along shorelines (Dzal et al. 2009). Long Point, Ontario, a known migratory bird stopover site, is also known to support individual silver-haired bats for up to three nights in late August to mid-September (Dzal et al. 2009, McGuire 2010).

Supporting the idea that coastlines represent migratory routes for bats, McGuire (2010) found that most bats departed Long Point along coastlines to the west or east, in addition to crossing Lake Erie. Hoary and little brown bats may also migrate through Long Point (Dzal et al. 2009). Additionally, bats may also migrate through Point Pelee, Ontario, and Whitefish Point, Michigan (Allen Kurta, Eastern Michigan University, personal communication). Other coastlines may also be important migratory routes, especially north-south oriented shorelines (Lesley Hale, Ontario Ministry of Natural Resources, personal communication).

Direct Mortality: Birds

Bats and migratory birds may be particularly sensitive to direct mortality impacts from wind energy infrastructure (see Arnett et al. 2007). Few available studies have measured collisions of birds with wind turbines in the Great Lakes basin near the shoreline. James (2008) estimated a mortality rate of 2-2.5 birds/turbine/year, mostly nocturnal migrating songbirds, and 0.4 raptors/turbine/year at 66 turbines along the northern Lake Erie shoreline in Ontario; no waterfowl were killed by turbines during the study period. He recommended that turbines be placed 825 ft (250 m) or more from the shores of large lakes to minimize mortality (James 2008). At Wolfe Island, Ontario, relatively high rates of mortality of birds colliding with turbines, 7 birds/turbine/6 months (1 July-31 December 2009), has occurred, including raptors and passerines, especially swallows (Stantec 2010).

Direct Mortality: Bats

Heavy bat use of Great Lakes coastlines may indicate high risk of bat mortality at wind energy facilities there. Fairly high mortality (13 and 14.8 bats/turbine), mostly of migratory species, was reported at facilities along the coastline of Lakes Huron and Ontario (Jaques Whiteford Stantec Limited 2009, Stantec 2010), perhaps associated with fall migration along the shorelines.

McGuire (2010) observed bats traveling as far as 3.6 miles (6 km) inland from stopover habitat on Long Point, but because of constraints on sampling times and locations, it was not possible to determine whether this distance was commonly or rarely traveled. A wind energy facility on Lake Huron reported no difference in mortality at turbines ranging from 2.4-6.7 miles (4-11 km) inland from the coastline (Jaques Whiteford Stantec Limited 2009). Therefore, we cannot currently prescribe quantitative buffers to reliably reduce bat mortality. Instead, we suggest that developers follow the operational guidelines we outline in Section IV C.10.

Displacement, Fragmentation, and Habitat Loss: Birds

As with other systems, coastal turbine placement can also affect birds through displacement and/or area abandonment. For instance, at Erie Shores Wind Farm (James 2008), construction activity in 2006 displaced a pair of Bald Eagles nesting within 1,320 ft (400 m) of a proposed turbine location, although the pair established a new nest about 2,970 ft (900 m) away and successfully raised two young. Hötker et al. (2006) found that shorebirds and gamebirds had reduced numbers at wind facilities, though not statistically significant for any breeding birds. Hötker et al. (2006) also synthesized results from studies outside the breeding season and found that negative impacts predominated and were statistically more negative than positive for various geese species, as well as Eurasian Wigeon (*Anas penelope*), Northern Lapwing (*Vanellus vanellus*), and European Golden-Plover (*Pluvialis apricaria*). Similar research should be conducted within the Great Lakes coastal marshes and shorelines, especially since the several species evaluated by Hötker et al. (2006) have North American counterparts such as American Wigeon (*Anas americana*) and American Golden-Plover (*Pluvialis dominica*).

Drewitt and Langston (2006) postulated that some wind facilities may cause birds to alter local or migratory flight paths, including coastal areas, thereby increasing energy expenditures and disrupting important ecological linkages among feeding, roosting, molting, and breeding areas. These consequences could lead to population declines. Although research needs to be conducted for the barrier phenomenon in the Great Lakes, Hötker et al. (2006) reviewed European studies examining barrier effects at coastal and nearshore sites on a wide variety of birds, including waterfowl, shorebird, gull, and songbird species. The authors found that some birds like herons, ducks, gulls, and terns were all less likely to change their original flight orientation when approaching a turbine, while others, including many other species, like geese, cranes, and many small bird species were more likely to exhibit relatively strong avoidance behavior in response to wind energy facilities. These responses may also vary with density of wind turbines.

Displacement, Fragmentation, and Habitat Loss: Herpetofauna

Although research has not been conducted specifically on the impacts of wind energy development on herpetofauna (amphibians and reptiles), they could be impacted if turbines, and associated infrastructure such as roads, are placed within coastal habitats. Frogs and toads (anurans) are sensitive to a variety of anthropogenic stressors, including fragmentation due to roads, and are widely suggested as indicators of ecological condition (Price et al. 2005). Coastal wetlands of the Great Lakes are used as breeding habitat by at least 14 species of anurans, many of which occur widely across the entire region (Hecnar 2004, Price et al. 2005). Great Lakes shorelines and coastal systems also provide habitat for species of conservation concern, such as the Lake Erie Watersnake (*Nerodia sipedon insularum*), a federally threatened species, and Blanding's turtle (*Emydoidea blandingii*), which is threatened in some parts of the Great Lakes region.

Even without considering wind energy development, land use and landscape changes within the Great Lakes basin have been particularly dramatic, especially the conversion of wetlands to agricultural, urban, and industrial land uses (Brazner 1997, Detenbeck et al. 1999). Point and non-point pollution (Marsalek and Ng 1989, The Nature Conservancy 1994), exotic species (Brazner et al. 1998, Herrick and Wolf 2005), and hydrological modifications (Meadows et al. 2005), among other factors, also affect the condition of Great Lakes wetlands and likely influence amphibian and reptile distributions in the coastal zone. Placing turbines in sensitive areas could further degrade coastal systems already degraded through habitat loss and fragmentation and negatively impact herpetofauna.

Displacement, Fragmentation, and Habitat Loss: Ecological Processes

Along with direct habitat loss, placement of wind energy infrastructure should consider the natural processes, like the interactions of wind and water, which maintain the dynamic coastal systems. Great Lakes coastal wetlands develop under conditions of large lake hydrology and disturbance imposed at various temporal and spatial scales, and they also contain biotic communities adapted to variable conditions (Keough et al. 1999). Coastal wetlands are configured along a hierarchy of hydrological factors and scales, including: a) local and short-term (seiches and ice action), b) watershed / lakewide/ annual (seasonal water-level change), and c) year-to-year water level fluctuations (Keough et al. 1999). Similarly, the Great Lakes coastal dune systems are heavily influenced by hydrologic actions of the Great Lakes (Peterson and Dersch 1981; Lichter 1998). Davidson-Arnott and Law (1996) found that year-to-year variations in sediment deposition on coastal dunes were also controlled by variations in beach width, related to changes in lake levels and to local beach morphodynamics. Construction of turbines and transmission infrastructure such as berms, levees, etc., could possibly interfere with these processes, thereby impacting natural system configuration and sustainability.

Degradation of coastal habitats could have impacts on nearshore/offshore biota and the ecosystem services provided by the Great Lakes waters. Wetlands occupying the flooded lower reaches of Great Lakes tributaries are probably important in maintaining and enhancing the water and sediment quality of the lakes (Krieger 2003). Water levels throughout the Laurentian Great Lakes have decreased in recent years; consequently, wetland areas with standing water and hydraulic residence times have decreased, probably reducing the effectiveness of the wetlands in mitigating pollution (Krieger 2003). Preservation of existing coastal wetlands would likely help with overall capacity to process material received from upstream, before such nutrients and sediments were washed into the Great Lakes.

Caveats

More research is needed better define buffers in the coastal zone. Current guidelines (e.g., New York State Department of Environmental Conservation 2009), with some supporting documentation (e.g., Ewert et al. 2005), suggest that wind turbines placed within 3.1-5 miles (5-8 km) of the Great Lakes are more likely to have significant interactions with wildlife than turbines placed further inland. This includes migratory bird (waterbirds, shorebirds, and landbirds, including raptors) and bat concentration areas, perhaps especially where many birds are descending to and ascending from stopover sites or moving between foraging and roosting/nesting sites. However, Guarnaccia and Kerlinger (2007) recommend exclusion zones for wind turbine development within 0.25 miles (<400 m) of Lake Erie.

The development buffer we recommend below is derived from the research and guidelines cited in the preceding paragraphs, and, like the offshore sections, data from Cooper et al. (2004), which in part was a vertical radar study conducted for the proposed Chautauqua wind energy facility located 3.7 miles (6 km) south of Lake Erie. We recommend a buffer from shore to 5 miles (8 km) to minimize risk to migrants, although this is a temporary placeholder until more data are available on coastal nocturnal migration. This distance should also encompass many coastal and shoreline processes, as well as island habitats that are crucial for colonial nesting waterbirds and migratory birds. However, as more studies are conducted and possible consequences of wind energy developments on coastal process are empirically modeled, the 5 mile (8 km) buffer will be refined and modified to reflect the wide range of Great Lakes shoreline characteristics.

Recommendations

We recommend the following guidelines to protect biodiversity and ecosystem processes in the coastal zone.

- We recommend that wind energy development be avoided within 5 miles (8 km) of the nearest coast or shoreline, either mainland or island.
- The operational mitigation described in Section IV C.10 should be followed to protect migratory bats from turbine-related mortality.

C.5. Grasslands, Open Lands, and Savannas (excluding Agricultural Lands)

Introduction

Grasslands and open lands include prairies, old fields, sedge meadows, pastures, savannas, imbedded wetlands, and alvars. Sensitivity for siting wind turbines within or near grasslands and minimizing impacts is critical, considering the extreme loss of native grassland habitats that has occurred in the Great Lakes region and decline of associated species (see Walk et al. 2010a). Analyses of Breeding Bird Survey population trends by bird-habitat association, nest location, and migratory strategy groups showed that grassland bird species had exhibited more extensive population declines between 1966 and 1993 than other groups of Midwestern breeding bird species (Herkert 1995), and these trends are likely continuing (North American Bird Conservation Initiative 2009). We briefly review evidence documenting the potential impacts of wind energy development to grassland species and ecological processes, especially for bird species thought to be highly area-sensitive (Greater Prairie Chicken) and where the Great Lakes region is a particularly important of their range (Henslow's Sparrow). Because habitat fragmentation and loss appears to affect grassland biota more than direct mortality from collisions with turbines, we emphasize fragmentation and habitat loss considerations in this section.

Direct Mortality: Birds

There is little evidence that direct mortality of birds striking turbines in grasslands differs from other habitat (see Section IV C.1).

Displacement, Fragmentation, and Habitat Loss: Birds

Many grassland bird species may be particularly vulnerable to wind energy development because of their sensitivity to habitat fragmentation, perhaps especially in native prairies that support high species richness (see Robertson et al. 2010). Johnson (2001) reviewed studies of area-sensitivity in grassland and wetland birds and found that some species, such as Northern Harrier (*Circus cyaneus*), favored large habitat patches in one or more studies and that other species, such as Grasshopper Sparrow (*Ammodramus savannarum*) were edge-averse. Herkert et al. (1996) suggest that viable populations of many grassland bird species are probably best supported by grasslands of over 2,540 acres (1,000 ha). Sample and Mossman (1997) and Johnson et al. (2010) have articulated specific criteria for grassland area and configuration needed to maintain a full suite of grassland birds at different spatial scales (see these papers for more specific guidance). Henslow's Sparrows are most often detected in grasslands >76 acres (30 ha) (Herkert 2003), and Greater Prairie Chicken minimum landscape area has been estimated to be from 1,500-10,160 acres (610-4,000 ha) (*in* Svedarsky et al. 2003). Spatial design of wind energy projects to minimize potential effects on breeding grassland birds based on these conceptual models should be considered.

Some grassland birds also display behavioral responses to infrastructure. The Greater Prairie-Chicken, which reaches its easternmost limits in Illinois, Wisconsin, and Minnesota, may be the most sensitive grassland species to fragmentation and associated infrastructure (roads, buildings, and tall structures) in the Great Lakes states. Robel (2002) predicted that utility-scale (1.5 MW) wind turbines would create an approximate 1 mile (1,600 m) radius avoidance zone for Greater Prairie-Chicken nesting and brood-rearing activities. Sharp-tailed Grouse (*Tympanuchus phasianellus*) may be less sensitive to fragmentation and associated infrastructure, but they are thought to avoid areas up to 2,577 ft (781 m) from roads and structures, potentially including wind turbines, placed in grasslands (citations in Mabey and Paul 2007, National Wind Coordinating Collaborative 2010). Henslow's Sparrows also avoid tall structures (Illinois Department of Natural Resources 2007).

Furthermore, facultative grassland birds, especially those associated with wet prairies and imbedded wetlands (e.g., migratory shorebirds and secretive marshbirds), may be affected by displacement from wind turbine construction/operation. Leddy (1996) found that reduced avian use of Conservation

Reserve Program (CRP) grasslands near turbines was attributed to avoidance of turbine noise and maintenance activities, or reduced habitat effectiveness because of the presence of access roads and large gravel pads surrounding turbines; CRP grasslands are among the few remaining areas in the Great Lakes region for grassland bird species, which are rapidly declining (Askins 1993). However, preliminary results from the Stateline (Oregon/Washington) Wind Project suggest a relatively small-scale impact of the wind facility on grassland nesting passerines, with a large portion of the impact due to direct loss of habitat from turbine pads and roads and temporary disturbance of habitat between turbines and road shoulders (Erickson et al. 2004).

Leddy et al. (1999) found that densities of male songbirds were significantly lower in CRP grasslands containing turbines than in CRP grasslands without turbines; 600 ft (180 m) buffers from turbines were sufficient to increase bird densities to those four times greater than densities near turbines. Johnson et al. (2000) found a similar-sized effect of turbines: the area of reduced use by birds was limited primarily to those areas within 330 ft (100 m) of the turbines. These effects may be disproportionately great in small habitat patches, especially those occupied by species such as the Red-headed Woodpecker (*Melanerpes erythrocephalus*), which uses edges and small habitat patches extensively (see Smith et al. 2000).

Displacement, Fragmentation and Habitat Loss: Insects and Herpetofauna

Other species associated with diverse grassland or savanna habitat may also be at risk from development of intact grassland such as prairie-obligate insects that inhabit isolated prairie and savanna patches as small as 1.3 acres (0.5 ha) in the Chicago region (Panzer et al. 2010). At Ryan Wetlands and Sand Prairie Natural Area, Illinois, a buffer of 1,320 ft (400 m) was established around a perched wetland that protects Blanding's turtles and the regal fritillary butterfly (*Speyeria idalia*). Although the effectiveness of this buffer was not described (Illinois Department of Natural Resources 2007), minimizing disruption of even small grassland patches, especially native prairie, by creating buffers is prudent.

Caveats

At least for grassland bird species, relatively large grasslands in relatively intact landscapes are generally thought to provide better habitat for grassland birds than small grasslands in more highly altered landscapes (Herkert et al. 1996, Sample and Mossman 1997) but interactions are complex and species-specific (Winter et al. 2006). Even small grasslands (7.6-360 acres [<3-142 ha]) can support productive populations of Dickcissels (*Spiza americana*) and Eastern Meadowlarks (*Sturnella magna*) in Illinois (Walk et al. 2010b). Our recommendations, then, are primarily directed at maintaining (1) remaining native prairie and savanna habitat and (2) populations of two grassland bird species – Greater Prairie-Chicken and Henslow's Sparrow – that occur in the Great Lakes region and are of particularly high conservation concern.

Recommendations

Because of their sensitivity to fragmentation and behavioral responses to turbine construction, operation, and maintenance, grassland birds, rather than other species or processes, drive our recommendations for development in or near grassland habitat in the Great Lakes region.

- Because of the scarcity of grassland habitat, we recommend avoiding construction in patches of grassland >76 acres (30 ha) in the Great Lakes region to minimize effects on Henslow's Sparrow.
- We recommend 1 mile (1.6 km) buffers around grassland landscapes supporting Greater Prairie-Chicken nesting and brood-rearing (Robel 2002).

- We recommend maintaining 660 ft (200 m) buffers around grasslands not supporting Greater Prairie Chickens, consistent with that recommended by Guarnaccia and Kerlinger (2007) for high diversity grassland bird areas in northwestern Ohio.
- Small patches of remnant undisturbed prairie or savanna of any size should be avoided to maintain populations of prairie and savanna-dependent insects, prairie-obligate plant species, and bird species such as Red-headed Woodpecker.

C.6. Forests

Introduction

Forests contain a diversity of species that may be particularly vulnerable to the effects of habitat fragmentation. Here, we focus on birds and bats because they are likely to be the most sensitive to direct mortality, habitat loss, and fragmentation. The herpetofauna may also be affected where inland wetlands are located in forests (see Section IV C.7).

Direct Mortality: Birds

See Section IV C.1.

Direct Mortality: Bats

In the United States, hoary bats are the bat species most frequently killed by turbines (41% of studies surveyed by Kunz et al. 2007b). Large numbers of eastern red (23%), tri-colored bat (*Perimyotis* [formerly *Pipstrellus*] *subflavus*, formerly eastern pipistrelle; 11%), and silver-haired (8%) bats have also been killed by turbines. Of these, hoary, eastern red, and silver-haired bats are all tree-roosting, long distance migrants; they are generally considered to be the species facing the most serious threat of direct turbine-related mortality. Seminole (*Lasiurus seminolus*), little brown, northern long-eared (or northern myotis; *Myotis septentrionalis*), big brown, Brazilian free-tailed (*Tadarida brasiliensis*) and Indiana bats have also been recorded as fatalities at wind turbines (Kunz et al. 2007b, West Inc. 2011). All of these except Seminole and Brazilian free-tailed bats (which do not occur in the Great Lakes region) use forest or forest edges in the Great Lakes region as summer habitat or while foraging for insects (Kurta 1995, Megan Seymour, U.S. Fish and Wildlife Service, personal communication).

Forest clearings and edges may represent high-risk sites for turbine placement. Bats may experience a high risk of mortality when they forage on insects that are attracted to forest clearings, to tall objects in the landscape, or to brightly colored turbine blades (Cryan and Barclay 2009, Long et al. 2010, Rydell et al. 2010). Alternatively, tree-roosting bats may be attracted to turbines for potential roosts or to find mates because turbines resemble tall trees (Cryan and Barclay 2009). Bat activity may be higher in good bat habitat such as forest edges, ridges, wetlands, or riparian areas, but it is unclear whether bat activity near the ground should be related to bat activity at the height in the air column occupied by turbine blades. So far, evidence suggests that among turbines at a single site, turbines farther from good bat habitat have equivalent rates of mortality than turbines nearer good bat habitat (Arnett et al. 2008, Lesley Hale, Ontario Ministry of Natural Resources, personal communication). The infrastructure associated with wind energy development, such as roads, may also represent a mortality threat, as bats are known to be killed by cars (Russell et al. 2008).

Although these aspects of bat behavior could expose bats to the threat of wind energy development, most mortality occurs among migratory species during the fall migration. This suggests that some facet of behavior specific to fall migration, foraging during migration, roosting during migration, or some other behavior restricted to migratory species is driving bat vulnerability to collisions and barotrauma (Cryan and Barclay 2009). As discussed in Section IV C.2, however, it is difficult to relate bat migration or bat swarming and hibernacula use to spatial landscape features. Therefore, we recommend that developers follow the operational guidelines described in Section IV C.10.

Displacement, Fragmentation, and Habitat Loss: Birds

More intact landscapes, including large and small patches of habitat, are generally associated with more productive bird populations (Thompson 2005). Largely intact landscapes (>70% natural cover) in the Great Lakes region support source populations of area-sensitive breeding birds (Robinson et al. 1995); ground or open-cup nesters with nests in shrubs and trees may be most sensitive to fragmentation (Lampila et al. 2005). In landscapes with only scattered remaining patches of habitat, these habitat patches serve as refugia for migrating birds. Large forest blocks of at least 10,160 acres (>4,000 ha) surrounded by agricultural or urban landscapes may be especially important for breeding birds such as Wood Thrush (*Hylocichla mustelina*) (Robinson et al. 1995) and perhaps especially sensitive to fragmentation (Chalfoun et al. 2002, Thompson 2005). Models have been developed to work toward goals of ensuring there are sufficient number of local landscapes (areas of 124 mi^2 [320 km^2]) to support regional bird populations (Twedt et al. 2006). Although similar modeling has not yet been done in the Great Lakes region, efforts are underway to work toward this goal (Bradly Potter, U.S. Fish and Wildlife Service, personal communication). Once done, more specific spatial recommendations can be made regarding the number and distribution of relatively unfragmented landscapes that should be maintained regionally.

Edge effects may have stronger influences on some bird species than others and may be correlated with some landscape metrics. In largely intact landscapes, such as the upper Midwest, where populations studied are largely source populations (Robinson et al. 1995, Flaspohler et al. 2001a), breeding bird productivity may not be significantly related to distance to edge (Howe et al. 1996; Ibarzabal and Desrochers 2001; King and DeGraaf 2002). Forest interior birds chose habitat away from edges, even though nest predation did not differ between edge and interior habitat (Ortega and Capen 2002). However, Ovenbirds (*Seiurus aurocapillus*) had relatively low nest success up to 1,650 ft (500 m) from clear cut edges in a largely forested landscape in northern Minnesota (Manolis et al. 2002). Nesting success (proportion of nests that fledged one or more young) may be lower up to 990 ft (300 m) from the edge of forest for ground nesters such as Ovenbird and Hermit Thrush (*Catharus guttatus*), but nesting success for canopy nesters was not related to distance from the edge of the forest in northern Wisconsin (Flaspohler et al. 2001b). Ground nesting birds may compensate for this lower nest success through higher clutch sizes at the edge (Flaspohler et al. 2001a).

However, there are sufficiently strong interactions among the proportion of a landscape in forest cover, patch size, and amount of edge to make it difficult to identify drivers of response of some breeding bird species to the amount and configuration of habitat available (Hartley and Hunter 1998, Villard 1998, Austen et al. 2001, Lahti 2001, Mazerolle and Hobson 2003, Parker et al. 2005, Kaiser and Lindell 2007, Stutchbury 2007). Nonetheless, migrating birds, even those species considered to be area-sensitive during the breeding season, may use a wide range of forested habitats in different patch sizes, configurations, and landscape contexts as stopover sites; even small patches may provide critical habitat, especially in highly altered landscapes (Mehlman et al. 2005). Consequently, buffers around forest patches will minimize risk to migrating birds as they descend to or ascend from these patches during migration.

Displacement, Fragmentation, and Habitat Loss: Bats

Generally, loss and fragmentation of suitable habitat are major threats to bat population persistence (Mickleburgh et al. 2002). Many species of Great Lakes bats roost in trees (Kurta 1995), so loss of trees may lead to habitat loss. However, because wind energy development typically uses only a small footprint embedded within a large matrix of potential habitat, rather than large-scale clearing, direct effects of habitat loss are likely to be small.

Fragmentation may affect bats, as they may follow linear landscape features such as tree rows, hedgerows, and forest edges to move among habitat patches while foraging (Verboom and Huitema 1997, Henderson and Broders 2008, Hein et al. 2009). Although avoidance behavior has not been documented, siting of wind turbines along these linear landscape features could potentially disrupt bat use of these important habitats and result in habitat fragmentation. However, bats may be less sensitive to fragmentation caused by small roads: 100% of tracked northern long-eared bats roosted within 2,310 ft (700 m) of a two-lane road (Foster and Kurta 1999), and roads did not deter bats from travelling along forest edges (Hein et al. 2009). Although the available evidence suggests that direct mortality from turbines is by far the most significant threat to bat populations, additional study is needed to quantify threats due to fragmentation, habitat loss, and displacement or avoidance behavior.

Displacement, Fragmentation, and Habitat Loss: Herpetofauna

Species whose range largely lies in the altered agricultural landscapes of the Great Lakes region (e.g., eastern copperbelly snake [*Nerodia erythrogaster neglecta*] and box turtle [*Terrapene carolina*]) may be susceptible to forest loss or fragmentation where these forest blocks are less than approximately 10,160 ac (4,000 ha) (Mancke and Gavin 2000). Fragmentation may result in increased mortality of herps as they cross roads and habitat loss due to changes in sheet flow of surface water, stream flow, and other abiotic processes needed to ensure suitable habitat (Fahrig et al. 1995).

Displacement, Fragmentation, and Habitat Loss: Terrestrial Mammals

Forest-dwelling mammal species seem to respond idiosyncratically to habitat fragmentation. American martens (*Martes americana*) are highly sensitive to forest fragmentation, almost disappearing from landscapes with <75% forest cover and avoiding forest edges, even though the abundance of their prey remained high (Hargis et al. 1999). Primarily because southern flying squirrels (*Glaucomys volans*), gray squirrels (*Sciurus carolinensis*), and red squirrels (*Tamiasciurus hudsonicus*) did not persist in forest fragments less than 10.1–12.7 acres (4–5 ha), larger forest fragments (up to 3,810 acres [1,500 ha]) contained greater small mammal diversity in Indiana; forest mammal diversity also decreased in isolated forest patches (Nupp and Swihart 2000). In contrast to those sensitive species, white-footed mice (*Peromyscus leucopus*) and eastern chipmunks (*Tamias striatus*) were more abundant in small forest patches (Nupp and Swihart 2000).

Using historical and current species area curves, Gurd et al. (2001) estimated that reserves would need to be about 1,950 mi^2 (5,000 km^2) to maintain populations of the Great Lakes region’s mammals. They also suggest that reserves larger than about 1,063 mi^2 (2,700 km^2) would have the greatest conservation value for mammals. However, some mammals are more restricted to forest interior habitat than others. These criteria apply primarily to northern parts of the Great Lakes region but underscore the need to avoid turbine construction in the largest intact forests in a landscape.

Caveats

The recommendations consider a landscape context, that is, development buffers at a particular site should be applied considering the surrounding land cover and not just the habitats and systems that comprise the patch(es) slated for wind turbine construction. Large forest patches may be the last remaining productive areas for area-sensitive bird species in some regions, and thus may be particularly sensitive to fragmentation effects. In landscapes where forest is scarce, remaining woodlots can provide areas for birds to forage and rest during migration, so these forest patches should be avoided, too. Our buffer recommendations were modified from Guarnaccia and Kerlinger (2007), but, considering the lack of data for migratory ascent/descent angles and species' sensitivity to disturbance, further study should refine these recommended setbacks.

Recommendations

The sensitivity of many forest species to edge effects and fragmentation drives our recommendations here.

- We recommend avoiding the construction of turbines or infrastructure such as roads in large intact forests (>5,080 acres [>2,000 ha]) in an agricultural or urban landscape (Mancke and Gavin 2000, Robinson et al. 1995).
- We further recommend minimizing wind energy development in remaining forests in landscapes (based on areas 2 mi^2 [5 km^2 or more]) where forest is scarce (<20% forested cover). Buffers from these patches be at least 0.25 miles (400 m) around woodlands >2.5 acres (1 ha) and at least 0.12 miles (200 m) around woodlands <2.5 acres (1 ha), to minimize risk for migratory birds ascending and descending to/from these forest patches.
- We also recommend avoiding wind energy development where it would reduce forest cover to less than 75% in landscapes where it is currently intact. Maintaining forest cover of at least 75% in landscapes results in higher productivity for birds and supports mammal populations.
- In those landscapes mostly covered with intact forest, it may be best to confine wind energy development to areas already deforested. Disturbing the interiors of forests and/or creating more edge habitat should be avoided in such landscapes.
- To protect forest roosting bats, turbines should apply the operational guidelines described in Section IV C.10.

C.7. Inland Wetlands

Introduction

Inland wetlands (wetlands not influenced by water level fluctuations of the Great Lakes), including wetlands as small as vernal pools, are imbedded in terrestrial systems or adjacent to lacustrine or riparian areas. We have focused on wetlands important to reptiles and amphibians, given their apparent sensitivity to change in both their aquatic and terrestrial habitats, and to breeding and migrating birds and bats.

Direct Mortality: Birds

See Section IV C.1.

Direct Mortality: Bats

So far, evidence suggests that among turbines at a single site, turbines farther from good bat habitat such as wetlands, riparian areas, or forest edges have equivalent rates of mortality to turbines nearer good bat habitat (Jain 2005, Arnett et al. 2008, Lesley Hale, Ontario Ministry of Natural Resources, personal communication, but see Jain et al. 2007). However, among wind energy developments, those nearer wetlands may have higher rates of mortality for some bat species. In particular, the Top of Iowa Windfarm and three facilities in southern Wisconsin were near large wetland complexes and reported higher-than-expected rates of mortality (6.4-50.5 bats/turbine), especially for little brown bats (Jain 2005, Gruver et al. 2009, BHE Environmental Inc. 2010, Drake et al. 2010). The three facilities in Wisconsin were also near the Neda Mine, a regionally important hibernaculum, so we can not conclude that the high rates of mortality for those facilities are a result of proximity to the Horicon Marsh. Because of this uncertainty, and because distances between developments and turbines were large, we do not prescribe siting guidelines around wetlands for bats. Instead, we rely on the operational guidelines described in Section IV C.10.

Displacement, fragmentation, and habitat loss: Birds

Breeding birds. Landscapes with extensive wetland complexes, such as Horicon Marsh, Wisconsin, or wetlands in the prairie pothole and aspen parkland regions of Minnesota, may be used by large numbers of nesting (and migrating) waterfowl (Soulliere et al. 2007), waterbirds (Wires et al. 2010) or shorebirds (see Potter et al. 2007). These landscapes may thus be sensitive to wind energy development although little is known about mortality of birds resulting from collisions with wind turbines in these areas.

Migrating birds: Shorebirds, cranes, rails. In the Great Lakes region, distribution of shorebirds and cranes during migration is relatively well known, but virtually nothing is known about locations of rails during migration. Sandhill Cranes (*Grus canadensis*), for example, congregate in especially large numbers during migration, in areas such as Jasper-Pulaski Fish and Wildlife Area, Indiana, and Phyllis Haehnle Memorial Sanctuary, Michigan (Wires et al. 2010). Many of these sites are identified as Important Bird Areas. Whooping Cranes occasionally occur at some of these same sites (Jack Dingledine, U.S. Fish and Wildlife Service, personal communication). Individuals disperse to feeding areas from these stopover sites, often flying at low altitudes, thus increasing the risk of collisions with tall structures during spring and fall migration. During migration, shorebirds are more widely distributed than cranes but some parts of the Great Lakes region, particularly those with mudflats, attract relatively large numbers of shorebirds. Regionally important areas for migrating shorebirds include Chautauqua National Wildlife Refuge, Illinois; the Lake Erie Marsh Region, Michigan and Ohio (Western Hemisphere Shorebird Reserve Network 2011); and west-central Indiana and east-central Illinois for migrating American Golden-Plovers. The Important Bird Area programs for each of the Great Lakes states describe other areas where shorebirds concentrate during migration. Guarnaccia and Kerlinger (2007) recommend buffers of 1,980 ft (600 m) around wetlands > 2.5 acres (1 ha) for wetlands that concentrate waterfowl; this same recommendation may be appropriate for other bird taxa as well.

Displacement, Fragmentation, and Habitat Loss: Herpetofauna

Blanding's turtles and spotted turtles (*Clemmys guttata*), long-lived species that are threatened or endangered throughout most of their ranges, may disperse up to 1 mile (1.6 km) from water (Center for Reptile and Amphibian Conservation and Management, Lee 2000, Minnesota Department of Natural Resources 2010). McDonough and Paton (2007) recommend 1,220 ft (370 m) buffers around wetlands to protect the habitat of spotted salamanders (*Ambystoma maculatum*). To protect the habitat of frogs and salamanders in Maine, a 495 ft (150 m) buffer around vernal pools in Maine has been recommended (University of Rhode Island 2001).

Caveats

Considering the lack of data for migratory ascent/descent angles and species' sensitivity to disturbance, further study could refine the setbacks recommended to protect birds in inland wetlands. Furthermore, dispersal of many species of reptiles and amphibians between breeding and non-breeding areas are poorly known, so setbacks based on reptiles and amphibians could change as more data become available.

Recommendations

Because herpetofauna and birds are vulnerable to habitat fragmentation, we recommend these guidelines to protect their habitat from turbine or infrastructure development.

- Infrastructure development and wind turbine placement should not separate herpetofauna breeding areas from non-breeding habitat.
- Following Guarnaccia and Kerlinger (2007), we recommend buffers of 1,980 ft (600 m) around wetlands >2.5 acres (1 ha) where waterfowl and waterbirds concentrate.
- Turbines near inland wetlands should apply the operational guidelines described in Section IV C.10.

C.8. Riparian Areas

Introduction

Riparian systems encompass habitats of critical conservation concern in the Great Lakes states, since they provide habitat for a number of at-risk species, including the endangered Indiana bat (Carter 2006). Meta-analysis of biological survey data has shown that riparian zones greatly increase regional species richness across the globe (Sabo et al. 2005) and provide important ecological services (Gundersen et al. 2010), such as improved water quality and reduced erosion. Landscapes containing riparian corridors and upland buffers are likely to be sensitive to alteration.

Direct Mortality, Displacement, Fragmentation, and Habitat Loss: Birds

Riparian forests are often considered important migratory corridors for Nearctic-Neotropical landbirds and also function as stopover points for birds within landscapes where original forest cover has been mostly eradicated (Fischer 2000, Moore 2000). Although riparian corridors are especially important for migratory birds in the western U.S. (Skagen et al. 2005), it is unclear if riparian corridors are used as stopover sites more than upland forests as stopover habitats in eastern states (Packet and Dunning 2009; Rodewald and Matthews 2005). Modifications of our buffer width recommendations await studies that document angles of ascent and descent to these sites under a range of weather conditions and additional studies of local movements of migrants within riparian corridors (Section V).

In agricultural or urban landscapes, riparian corridors may also preserve large tracts of breeding habitats for area-sensitive songbirds, like Wood Thrush, Cerulean Warbler (*Dendroica cerulea*), and Prothonotary Warbler (*Protonotaria citrea*). Avoiding or minimizing fragmentation of such breeding locales must also be a consideration when developing wind energy projects. In forested landscapes in Alberta, Ovenbirds were absent from 66 ft (20 m) wide buffer strips around streams but persisted in 330 ft (100 m) wide buffer strips (Lambert and Hannon 2000). Fischer (2000), based on a literature review of avian use of riparian zones, recommends buffers of at least 330 ft (100 m) around river corridors.

Direct Mortality, Displacement, Fragmentation, and Habitat Loss: Bats

Riparian areas may be important for both bat roosting habitat and migratory corridors. Furmankiewicz and Kucharska (2009) documented bats migrating along a large river in Poland. Rivers and other linear landscape features in the Great Lakes region may function similarly, but this hypothesis has not yet been adequately tested (Section V). Riparian areas may be particularly important habitats for endangered Indiana bats (Carter 2006). Other species of bats may also forage or roost in riparian areas but, so far, evidence suggests that among turbines at a single site, turbines farther from good bat habitat have equivalent rates of mortality than turbines nearer good bat habitat (Arnett et al. 2008, Lesley Hale, Ontario Ministry of Natural Resources, personal communication). Therefore, we rely on the operational guidelines described in Section IV C.10 to protect bats.

Displacement, Fragmentation, and Habitat Loss: Herpetofauna

Riparian terrestrial buffers also serve important roles for the conservation of semiaquatic species. The upland habitats surrounding wetlands can be used for various functions within amphibian and reptile life histories, including dispersal, foraging, and overwintering. Because these functions can involve different life stages, the extent of landscape required for each may differ annually or seasonally. Ficetola et al. (2009) found that 330-1,320 ft (100-400 m) of terrestrial habitat surrounding riparian zones were best for amphibians, but suggested that areas up to 4,959 ft (1.5 km) would be used by dispersing amphibians.

Caveats

Relative use of riparian corridors by migrating birds compared to other terrestrial habitats, by latitude, and by stream order, requires further study. Similarly, the angle of ascent and descent to riparian corridors is unknown. Consequently, we expect these recommendations to be refined as these studies are completed.

Recommendations

Reflecting increased perceived risk of bat mortality in sensitive areas, New York recommends additional study within 5 miles (8 km) of large river corridors (New York State Department of Environmental Conservation 2009). Wisconsin also recommends avoiding development near likely migratory corridors such as Great Lakes shorelines and large river valleys (Wisconsin Department of Natural Resources 2004). Ohio Department of Natural Resources (2009) recognizes a higher risk of impact for turbines sited closer than 1,650 ft (500 m) to large water bodies, including rivers. In Missouri, Roell (1994) concluded that riparian buffers should be at least 100 ft (30 m) wide in areas with floodplains and at least 50 ft (15 m) along streams without floodplains. Perry et al. (2001) suggest that riparian zones should be 200 ft (60 m) wide in northern Minnesota forested landscapes to maintain species and processes needed to maintain stream integrity. Lee et al. (2004) reviewed riparian buffer zone width guidelines from U.S. and Canadian jurisdictions, noting that the guidelines may not be validated by empirical data. They summarized average buffer guidelines for U.S. states/Canadian provinces: large permanent streams 79 ft/145 ft (24 m/44 m), small permanent stream 66 ft/99 ft (20 m/30 m), intermittent streams 53 ft/46 ft (16 m/14 m), small lakes 76 ft/155 ft (23 m/47 m), large lakes >10.9 acres (4.3 ha) 75 ft/181.5 ft (23 m/55 m). These recommendations are very general and not tied to particular species, community or process requirements.

We recommend the following spatial buffers around riparian areas:

- Smaller to moderate riparian corridors (mostly headwater streams, 1st to 5th order), especially in highly fragmented landscapes, should maintain a protective buffer of 0.12 miles (200 m), to protect habitat for semi-aquatic species. We tentatively support Guarnaccia and Kerlinger's (2007) recommendation of buffer of 0.12 miles (200 m) around riparian forests to minimize risk to migrating birds.
- Major rivers (6th order and above) that are corridors for migratory birds or provide stopover habitat (e.g., Ohio River) should maintain 1,650 ft (500 m) buffers.
- Turbines constructed in riparian areas should apply the operational mitigation described in Section IV C.10 to reduce bat and bird mortality.

C.9. Agricultural Lands

Introduction

Agricultural lands are highly human-impacted and host fewer species than many of the other systems included in this report. Therefore they may be among the more suitable sites for development (Section IV A). However, some agricultural lands may host vulnerable taxa, so they may be less suitable than other sites.

Direct Mortality and Habitat Use: Birds

Landbird migrant use of agricultural lands as stopover sites is relatively low (Bonter et al. 2009), and collisions of birds with wind turbines in agricultural settings are typically low (National Wind Coordinating Collaborative 2010). However, sod farms, pastures, and ephemeral pools of water on agricultural lands in the Great Lakes states can support many long-distance migratory shorebirds, including American Golden-Plover, Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*Tringa flavipes*), Least Sandpiper (*Calidris minutilla*), Pectoral Sandpiper (*Calidris melanotos*), Buff-breasted Sandpiper (*Tryngites subruficollis*), and Short-billed Dowitcher (*Limnodromus griseus*), during spring or fall migration. Row crop fields, particularly those with soybean stubble and >396 ft (120 m) from roads, can be globally significant for staging American Golden-Plover during spring in east-central Illinois and west-central Indiana (Braille 1999, Johnson 2003, O'Neal and Alessi 2008). Flooded agricultural lands, especially near portions of the Great Lakes such as Saginaw Bay and the Lake Erie basin (Petrie et al. 2002), are often and predictably used by shorebirds and waterfowl, particularly in spring. Since some agricultural landscapes contain wetlands or are often flooded, these sites should be carefully evaluated when planning siting of wind turbines.

Direct Mortality: Bats

Bat mortality varies greatly across agricultural habitats in the U.S. and Canada. Although mortality at some facilities is as low as 0.5 bats/turbine, some wind facilities in agricultural landscapes in Alabama, Iowa, New York, and Wisconsin have high bat mortality, nearly or exceeding 10 bats/turbine/year (Jain 2005, Arnett et al. 2008, Gruver et al. 2009). In 2009 and 2010, endangered Indiana bats were reported dead in a wind energy facility in an agricultural landscape in Indiana (West Inc. 2011). Because turbines in agricultural areas may have high bat mortality, we recommend that all turbines, even those built in agricultural areas, implement the operational mitigation described in Section IV C.10.

Caveats
Considering the lack of data for migratory ascent/descent angles and species' sensitivity to disturbance, further study may elucidate setbacks around Important Bird Areas in agricultural landscapes, in order to better abate direct mortality and area abandonment.

Recommendations
Although agricultural landscapes are probably among the best places to site wind turbines from the perspective of biodiversity conservation, there are a few conditions that warrant caution.

- We recommend that wind energy development be avoided at potential or designated Audubon Important Bird Areas in agricultural landscapes, including those that support significant assemblages of shorebirds, waterfowl, and waterbirds for short periods of time or irregularly, because these sites may be critical staging and/or nesting areas.
- Because bats are threatened by mortality at turbines even in agricultural landscapes, we recommend operational mitigation (Section IV C.10) for turbines constructed there.

C.10. Operational Guidelines

Introduction
Although we have prioritized siting guidelines for the protection of wildlife and ecological processes, additional operational guidelines are necessary to protect some taxa.

Bats
For bats, insufficient data on the relationships among site characteristics and mortality, insufficient data on migratory routes and behaviors, and high variability in mortality rates preclude relying on spatial guidelines. In contrast, operational mitigation has been shown to dramatically reduce mortality. Increasing cut-in speeds from the default 11.6 to 19.8 ft/sec (3.5 to 6 m/sec) reduces mortality by 44-93% (Arnett et al. 2010, Arnett et al. 2011, Baerwald et al. 2009) by shutting off turbines on low wind speed nights. This mitigation is warranted during the fall bat migratory and swarming season, 15 July - 30 September. While markedly reducing bat mortality, this operational mitigation causes negligible losses in power generation. For example, Arnett et al. (2010) report 0.3% or 1% losses in total annual output for feathering turbine blades below cut-in speeds of 16.5-21.0 ft/sec (5.0 or 6.5 m/s), respectively, for 75 days in late July-early October.

Other guidelines (Ontario Ministry of Natural Resources 2010) also require operational mitigation during nights in the fall with wind speeds below 5.5 m/s; these guidelines apply to all offshore turbines and any on-shore turbines where mortality has been documented above a mitigation threshold of 10 bats/turbine/year. Although this threshold represents a compromise value between the highest (70 bats/turbine) and lowest (0.1 bats/turbine) reported mortality rates (Arnett et al. 2008), available population data do not allow us to assess whether viable bat populations can sustain even mortality rates below 10 bats/turbine/year, so we do not know whether this threshold is sufficiently conservative (Section V). We recommend this operational mitigation for all turbines.

Long et al. (2010) found that insects are more attracted to yellow, white or gray, and to infrared or ultraviolet light, than other colors such as purple. Because bats may follow their insect prey towards turbines (Cryan and Barclay 2009), reducing insect attraction to turbines by applying paint least attractive to insects may also reduce bat mortality. However, this hypothesis requires further testing, so we make no recommendations about the color of wind turbines.

Birds

Kerlinger et al. (2010) concluded that mortality rates of birds at unlit and lit turbines were not significantly different where Federal Aviation Administration (FAA) lighting was used, but in a few cases non-FAA lighting, such as sodium vapor lamps at ground facilities near turbines, was associated with multi-bird fatalities during one foggy night. Guarnaccia and Kerlinger (2007) suggest that (1) lighting on turbines be minimized; (2) when lighting is used that FAA flashing beacons (L-864 red or white strobe) be used; and (3) steady burning (L-810) red FAA lights not be used. However, nearby bright, continuous lighting may attract migrating birds to the general area of the turbines resulting in increased bird collisions with turbines. Hüppop et al. (2006) suggest that experiments should test the brightness and color of wind turbine against collision rates. They suggest adjusting lighting to weather conditions, e.g. flashing-light with long intervals instead of continuous light in fog and drizzle.

In the western Lake Erie basin, Ross and Bingham (2008) suggested that shutting down turbines during the peak of spring migration, between late April and mid May, and the peak of fall migration, between mid-September and early October, when weather is favorable for migration, could reduce risk to 60-70% of migrants passing through the region each migration season. Favorable weather in spring for migration is associated with moderate southerly winds while light winds from the west are often associated with migration movements during the fall (Ross and Bingham 2008).

Caveats

Although we recommend a wind speed threshold at which to feather turbines, we do not know whether this threshold is sufficiently conservative to sustain viable bat populations that are currently at risk (see Section V).

Recommendations

- Feather turbines between sunset and sunrise, 15 July-30 September, when wind speeds are below 18.1 ft/sec (5.5 m/sec) to reduce bat mortality. These dates in the fall approximately delineate the fall migration and swarming season for bats (Arnett et al. 2008, U.S. Fish and Wildlife Service 2007b).
- During nights in which relatively high bird strikes are predicted (i.e., poor weather conditions, such as fog, during periods of considerable migration), operational mitigation should be applied, turning off turbines and adjusting rotor blades to minimize their surface relative to the main direction of migration. In the western Lake Erie basin, light, westerly winds near midnight in fall and southerly, moderate winds in spring are associated with large movements of migrating birds (Ross and Bingham 2008). This could be helpful in reducing collision risk and extent (Arnett et al. 2010, Baerwald et al. 2009, Hüppop et al. 2006).
- Avoid large-scale, continuous lighting of wind turbines (Winkelman 1992a-d, 1994; Hüppop et al. 2006; Gehring et al. 2009). However, measures should still be taken to make wind turbines more recognizable to birds, in order to abate potential collisions.

V. Research Needs, A Partial List.

To minimize possible cumulative impacts of direct mortality, habitat loss, and other ecological threats associated with offshore wind energy development, potential construction sites should be considered as part of an integral assessment framework (see Exo et al. 2003). However, making such assessments is currently hindered by the lack of data of flight behavior and migration routes for bird and bat species. Data also do not allow assessment of the relative magnitude of direct mortality, habitat loss, and avoidance behavior on population viabilities. Cumulative impacts on fish communities are equally difficult to estimate, since very little information is available on nearshore/offshore spawning and nursery sites. And unlike avifauna, in which a protocol exists to determine 'Important Bird Areas' (National Audubon Society 2010), we do not have whole-scale metrics to identify crucial habitats where development should be avoided or minimized for fish, bats, or other potentially sensitive taxa.

The development of a publicly available database of pre- and post-construction monitoring data on sensitive taxa, collected in standardized manner, would facilitate answering these research questions. We emphasize the need to develop such a database.

We identified several areas of research that would be valuable in improving guidelines for the siting of wind turbines to minimize impacts on biodiversity. This list is not intended to be an exhaustive description of research needs.

1) *What are the angles of ascent and descent of birds at stopover areas?* Given offshore turbine heights, these data will allow developers to offset construction from coastal and island sites at distances that reduce risk of nocturnal migrants striking rotor-swept areas.

2) *How do endangered and threatened species respond to wind turbines?* Additional research is needed to determine how these species respond to wind turbines and if this varies with weather, landscape or site-specific features.

3) *How do offshore turbines affect the densities and distributions of pelagic bird species?* To better assess short-term and long-term habitat loss, pre- and post-construction densities and distributions of pelagic bird species should be evaluated via transect surveys for migratory and over-wintering seasons.

4) *How important to birds are barrier effects, disruption of ecological routes, and habitat loss caused by turbine construction and operation?* Visual observations and flight call recordings to detect movements of passage migrants and foraging birds – including avoidance behavior in response to construction activities and turbines – should be conducted pre- and post-construction. This could then be integrated with the above transect data across landscapes to better quantify cumulative impacts on migrant energy demands and habitat availability.

5) *Do birds use riparian corridors as migration routes and, if so, what types of riparian corridors are used most extensively?* Determining how birds use riparian corridors of different widths, lengths (of continuous riparian habitat), and orientation of the corridor with respect to the cardinal directions would all help identify which riparian corridors might be most sensitive to wind energy development.

6) *Where are migratory bird routes and pelagic staging areas?* Expert opinion and some studies indicate that concentrations of migrating birds occur on peninsulas and islands but additional work is needed to show the patterns all across the Great Lakes region.

7) *How sensitive are fish communities and spawning habitats to the short- and long-term impacts of disturbances?* Buffers, and spatially explicit areas where construction must be avoided, should be articulated. Continued surveys and identification of important offshore fish spawning/nursery habitats is also crucial to make better siting decisions.

8) *What are population sizes and demographic rates for the bat species experiencing direct mortality?* Can populations sustain any level of turbine-related mortality (locally or range-wide) and continue to persist? There are currently insufficient data to make this determination (Ohio Department of Natural Resources 2009).

9) *Are operational guidelines in the fall sufficient to keep annual bat mortality below a reasonable threshold that allows for population persistence?* If not, would additional operational mitigation during the spring and summer be effective in protecting bats during spring migration, at maternity colonies, or at other summer habitat? Would extending mitigation into the periods just before sunset or just after sunrise reduce bat mortality? Combined with accurate estimates of demographic rates and the effectiveness of different operational mitigation strategies, modeling studies could investigate total turbine-related mortality and determine the relative importance of fall, spring, or summer mitigation, or early-morning and late-evening mitigation, in terms of bat mortality.

10) *Do bats use consistent migratory corridors in the Great Lakes region?* Currently, there seems to be support for a migratory route for silver-haired, hoary, and little brown bats through Long Point, ON, with a stopover location there for at least silver-haired bats (Dzal et al. 2009, McGuire 2010). Certainly other migratory routes exist in the Great Lakes region, perhaps along north-south shorelines of the Great Lakes (Lesley Hale, Ontario Ministry of Natural Resources, personal communication). Furthermore, we need to know how wide these corridors are. A study of turbines ranging from about 2.5-6.8 miles (4 km-11 km) east of Lake Huron did not report greater mortality nearer the lakeshore (Jaques Whiteford Stantec Limited 2009), suggesting that this migration route is fairly wide.

11) *Where are major bat hibernacula in the Great Lakes region?* Data on the number and size of hibernacula for different species of bats do exist. For example, the spatial and size distributions of the Indiana bat are well understood (U.S. Fish and Wildlife Service 2007b). Major mapping efforts have also been undertaken to understand the spread of white nose syndrome (U.S. Fish and Wildlife Service 2010b). Additional data on bat hibernacula may also be held by state Natural Heritage programs. However, these data have not been compiled across states and across species for a region-wide understanding of the spatial and size distributions of bat hibernacula.

12) *How far from hibernacula do bats forage and roost during fall swarming?* Studies of several species of bat indicate that they roost in trees or forage 0.2-37.2 miles (0.3-60 km) from the hibernaculum during the swarming season (U.S. Fish and Wildlife Service 2007b). Although it seems that bats may venture farther from larger hibernacula than smaller (U.S. Fish and Wildlife

Service 2007b), further data are required before we can reliably predict the swarming behavior of different species of bats around hibernacula of different sizes.

13) *How far do bats migrate from hibernacula to their summer colonies?* Except for the relatively intensively-studied Indiana bat, little is known about bat movement between hibernacula and summer colonies. Most of the 105 Indiana bats radio tracked with aircraft in New York traveled less than 40.3 miles (65 km) from hibernacula to summer colonies (U.S. Fish and Wildlife Service 2007b; Al Hicks, New York State Department of Environmental Conservation, personal communication). However, distances migrated may vary substantially across the Great Lakes region. In Pennsylvania, five female Indiana bats traveled 45.9-87.4 miles (74-141 km) between hibernacula and summer colonies (Butchkoski and Turner 2008). Four Indiana bats with summer colonies in Michigan migrated an average of 285.2 miles (460 km) and up to 330 miles (532 km) to hibernacula in Indiana and Kentucky (Kurta and Murray 2002).

14) *Do bats use stopover sites during north-south migration or to and from hibernacula, and how far do bats venture in search of habitat while migrating?* Almost no data are available to assess this question. McGuire's (2010) study on Long Point, Ontario, found that some bats went as far as 3.6 miles (6 km) inland from the stopover site, but because of constraints on sampling locations and times, it is not possible to determine whether this distance is commonly or rarely traveled (Liam McGuire, personal communication)

15) *How high do bats migrate, north-south or to and from hibernacula?* Do bats migrate through the portion of airspace occupied by turbine blades, or do they fly above or below the rotor-swept area? Is the elevation constant through time or space? These questions have not yet been answered empirically.

16) *Are bats attracted to turbines?* If so, from what distance, horizontally or vertically, are they attracted? Are bats vulnerable during migratory flight, or only during stopovers? How far must turbines be placed from migratory routes or stopover locations to be outside the range of attraction? At very local scales (a few meters) bats do seem attracted to turbines, investigating and landing on blades and monopoles as they do trees (Horn et al 2008). However, whether bats are attracted to the light, height, or sound of turbines from greater distances (i.e., on the scale of kilometers) is unknown (Cryan and Barclay 2009).

17) *What role do insects play in bat attraction to turbines?* Do bats follow their insect prey to turbines and suffer mortality as a result? Recent research has indicated that insects are attracted to some colors of turbine paint more than others (Long et al. 2010). Combined with information on insect seasonal migration, this could explain why bats are killed during the fall migration (Rydell et al. 2010). However, this hypothesis has been insufficiently tested.

18) *Does wind energy development cause adverse effects on bats via injury, fragmentation, habitat loss, or avoidance behavior?* If so, how important to population persistence are these effects, relative to direct mortality?

19) *What impact does operational mitigation have on annual power output?* Available data from one study suggests that power loss is minimal (Arnett et al. 2010). However, another study suggested

that profit loss may be larger, depending on a number of economic and environmental factors, such as the market price of electricity, contractual obligations, the frequency of wind speeds below the increased cut-in speed, and the engineering capacity to feather turbines only when mitigation is recommended (Baerwald et al. 2009).

20) *What impact do turbines have on insects?* Turbine development might affect migrant or resident insects in grasslands or other habitat types through direct mortality, habitat loss, or fragmentation, but few studies have been conducted to quantify these effects.

21) *What spatial arrangement of turbines will minimize impacts on birds and bats?* Some research has suggested that clumped distributions may reduce mortality over linear arrangements of turbines (Winkleman 1992a-d), but further study is required to test the generality of this pattern and its applicability to Great Lakes region biota. A meta-analysis of European literature to compare turbine arrangements might begin to test this hypothesis.

22) *What are the cumulative impacts of direct mortality, long- and short-term habitat loss, fragmentation, and behavioral responses on the biodiversity and ecosystem functions of the Great Lakes region?*

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VII. Additional Sources of Information

A. Regional and National Sources of Information on Wind Energy Siting: A Selection

- American Bird Conservancy. Excellent review of many aspects of wind energy, including siting. http://www.abcbirds.org/abcprograms/policy/wind/index.html
- American Wind Energy Association. 2008. Critical environmental issues analysis. http://www.awea.org/sitinghandbook
- American Wind Wildlife Institute. http://www.awwi.org (see also Wind and Wildlife Assessment Tool for approximately 400 vertebrate species across the United States: http://wind.tnc.org/awwi
- Association of Fish and Wildlife Agencies. 2007. Wind power siting, incentives, and wildlife guidelines in the United States. http://www.fishwildlife.org/pdfs/WindPower/AFWAWindPowerFinalReport.pdf
- A bibliography of bat fatality, activity, and interactions with wind turbines. Prepared by Gregory D. Johnson (Western EcoSystems Technology, Inc.) and Edward B. Arnett (Bat Conservation International). Updated 4 March 2011. ftp:gis.dipbsf.uninsubria.it/Eolico/Bat and Wind Turbine Bibliography revised 7-28-08.pdf
- Canadian Wildlife Service & Environment Canada. 2007. *Wind turbines and birds-A guidance document for environmental assessment.* http://www.fws.gov/midwest/wind/guidance/canadianeguidelines.pdf
- Conserve OnLine. http://www.conserveonline.org/
- National Wind Coordinating Collaborative. http://www.nationalwind.org
- Stickland, D., E. Arnett, W. Erickson, D. Johnson, G. Johnson, M. Morrison, J. Shaffer, and W. Warren-Hicks. 2011. Comprehensive guide to studying wind energy/wildlife interactions. Prepared for the National Wind Coordinating Collaborative. Washington, D.C., USA.
- U.S. Department of Energy, National Renewable Energy Laboratory. Wind energy maps. High resolution: http://www.nrel.gov/gis/images/map_wind_national_hi-res.jpg
  Low resolution: http://www.nrel.gov/gis/images/map_wind_national_lo-res.jpg
- U.S. Fish and Wildlife Service. 2011. U.S. Fish and Wildlife Service Draft Voluntary Land-Based Wind Energy Guidelines. http://www.fws.gov/windenergy/docs/Wind_Energy_Guidelines_2_15_2011FINAL.pdf or http://www.fws.gov/windenergy/guidance.html
- U.S. Fish and Wildlife Service. 2011. The Draft Eagle Conservation Plan Guidance. http://www.fws.gov/windnergy/docs/ECP_draft_guidance_2_10_final_clean_omb.pdf

B. Great Lakes States and Provinces Sources of Information on Wind Energy Siting Relative to Wildlife, including maps showing sensitive natural resources areas to wind energy development/wind working groups by state

- Great Lakes Fisheries Commission
  - *Lake Erie Committee's 2009 Position Statement on Offshore Wind Power*. http://www.glfc.org/lakecom/lec/lechome.php
  - *Conserving Great Lakes aquatic habitat from lakebed alteration proposals.* http://www.glfc.org/research/reports/Dempsey.pdf
  - *Lakebed Alteration Decision Support Tool (LADST)* http://ifrgis.snre.umich.edu/projects/LADST/ladst.shtml
- Great Lakes Wind Atlas. http://glin/net/wind/
- Great Lakes Wind Collaborative. http://glc.org/energy/wind
  - *Offshore siting principles and guidelines for wind development on the Great Lakes.* October 2009. http://www.glc.org/energy/wind/pdf/Offshore-Siting-Principles-and-Guidelines-for-Wind-Development-on-the-Great-Lakes_FINAL.pdf
  - *State and Provincial Land-based Wind Farm Siting Policy in the Great Lakes Region: Summary and Analysis*. January 2010. (http://www.glc.org/energy/wind/pdf/GLWC-LandBasedSiting-Jan2010.pdf)
- Illinois Wind Working Group. http://www.wind.ilstu.edu
- Indiana Wind Working Group. http://www.in.gov/oed/2421.htm
- Iowa. *Wind energy and wildlife resource management in Iowa: avoiding potential conflicts.* http://www.iowadnr.gov/wildlife/diversity/files/wind_wildliferecs.pdf
- Michigan
  - Michigan Wind Working Group. *Michigan Land Use Siting Guidelines for Wind Energy Systems.* March 2007. http://docstoc.com/docs/22046466/Michigan-Land-Use-Guidelines-for-Siting-Wind-Energy-Systems/
  - Michigan State University, The Land Policy Institute. *The Land Policy Institute Wind Prospecting Tool Prototype. Preliminary Summary.* A GIS-based depiction of wind resources, land and ecological considerations, and other baseline features in Michigan. http://www.landpolicy.msu.edu/wpt/WPT_summary.pdf
  - Michigan Great Lakes Wind Council. *Report of the Michigan Great Lakes Wind Council.* Sept. 1, 2009. Recommendations for wind turbine siting in the Michigan portion of the Great Lakes. http://www.michiganglowcouncil.org
  - University of Michigan (Institute for Fisheries Research) /Michigan Department of Natural Resources. *Lakebed Alteration Decision Support Tool (LADST).* http://ifrgis.snre.umich.edu/projects/LADST/ladst.shtml
- Minnesota Public Utilities Commission. *General wind turbine permit, setbacks and standards for large wind energy conversion (LWECS) permitted pursuant to Minnesota statute 216F.08.* http://energyfacilities.puc.state.mn.us/documents/19302/
- New York State Department of Environmental Conservation. *Draft guidelines for conducting bird and bat studies at commercial wind energy projects.* http://www.dec.ny.gov/docs/wildlife_pdf/windguidelines.pdf
- Ohio.

- Ohio Department of Natural Resources. Maps showing sensitive areas to wind power development, terrestrial and Lake Erie available. Criteria for defining sensitivity defined. http://www.dnr.state.oh.us/LakeErie/WindEnergyRules/tabid/21234/Default.aspx
- Ohio Department of Natural Resources. 2009. On-shore bird and bat pre- and post-construction monitoring protocol for commercial wind energy facilities in Ohio. http://www.dnr.state.oh.us/LinkClick.aspx?fileticket=loJTSEwL2uE%3d&tabid=21467
- Ohio Wind Working Group. http://www.ohiowind.org

- Pennsylvania.
  - Pennsylvania Department of Conservation and Natural Resources. 2007. Wildlife monitoring proposals for potential industrial wind turbine sites on DCNR lands. http://www.dcnr.state.pa.us/info/wind/documents/draft_wildlife_monitoring_on_sfl_052207.pdf
  - Pennsylvania Energy Impacts Assessment. The Nature Conservancy. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/explore/the-energy-equation.xml
  - Pennsylvania Game Commission. *Pennsylvania Game Commission Wind Energy Voluntary Cooperation Agreement to Protect Wildlife.* February 2007. http://www.crisciassociates.com/Newsletter/docs/3/GameComWindAgree.pdf http://www.portal.state.pa.us/portal/server.pt?open=514&objID=613068&mode=2
  - Pennsylvania Wind Farms and Wildlife Collaborative. http://www.dcnr.state.pa.us/info/wind/resource1.aspx
- Ontario Ministry of Natural Resources. 2010. Bats and bat habitats: guidelines for wind power projects. http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@renewable/documents/document/289694.pdf
- Wisconsin.
  - Wisconsin Department of Natural Resources. *Considering natural resource issues in windfarm siting in Wisconsin. A guidance.* http://www.dnr.wi.gov/org/es/science/energy/wind/guidelines.pdf
  - Public Service Commission of Wisconsin. *Harnessing Wisconsin's Energy Resources: An initial investigation into Great Lakes Wind Development.* http://psc.wi.gov/initiatives/globalWarming/documents/wowreport11509.pdf

C. TNC Ecoregional and Lake Basin Assessments for Great Lakes States and Provinces

Assessment Name: Central Tallgrass Prairie
Ecoregions: NA0804. Central Tallgrass Prairie
http://conserveonline.org/coldocs/2000/11/ctp.pdf (terrestrial only)
http://conserveonline.org/library/central-tallgrass-prairie-ecoregional-assessment (freshwater and terrestrial)

Assessment Name: Cumberlands and Southern Ridge and Valley
Ecoregions: NA0403. Cumberlands and Southern Ridge Valley
http://conserveonline.org/coldocs/2004/01/CSRVPlan.pdf

Assessment Name: East Gulf Coastal Plain
Ecoregions: NA0507. East Gulf Coastal Plain

http://conserveonline.org/library/egcp_ERA_june03.pdf

Assessment Name: Great Lakes
Ecoregions: NA0404. Great Lakes
http://conserveonline.org/coldocs/2001/06/Summdoc.PDF

Assessment Name: High Allegheny Plateau
Ecoregions: NA0405. High Allegheny Plateau
http://conserveonline.org/coldocs/2005/03/HALplan.pdf

Assessment Name: Interior Low Plateau
Ecoregions: NA0406. Interior Low Plateau
http://conserveonline.org/coldocs/2005/01/ILP_plan.pdf

Assessment Name: Lower New England / Northern Piedmont
Ecoregions: NA0407. Lower New England / Northern Piedmont
http://conserveonline.org/coldocs/2005/03/LNEplanwithAppendices.pdf

Assessment Name: Mississippi River Alluvial Plain
Ecoregions: NA0408. Mississippi River Alluvial Plain
http://conserveonline.org/library/conservation-planning-in-the-mississippi-river

Assessment Name: North Central Tillplain
Ecoregions: NA0410. North Central Tillplain
http://conserveonline.org/coldocs/2003/11/NCT0703.pdf

Assessment Name: Northern Appalachian / Acadian
Ecoregions: NA0411. Northern Appalachian-Boreal Forest
http://conserveonline.org/workspaces/ecs/napaj/nap

Assessment Name: Northern Tallgrass Prairie
Ecoregions: NA0811. Northern Tallgrass Prairie
http://conserveonline.org/coldocs/2000/11/plan_main.pdf
Bird Addenum: http://conserveonline.org/coldocs/2000/12/Bird_m_1.pdf

Assessment Name: Ozarks
Ecoregions: NA0413. Ozarks
http://conserveonline.org/coldocs/2004/01/Ozarks_Ecoregional_Conservation_Assessment.pdf

Assessment Name: Prairie-Forest Border
Ecoregions: NA0415. Prairie-Forest Border
http://conserveonline.org/library/PrairieForestBorder_FINALREPORT_wExhibits.pdf/view.html#

Assessment Name: St. Lawrence - Champlain Valley
Ecoregions: NA0417. St. Lawrence-Champlain Valley
http://conserveonline.org/coldocs/2005/03/STL_report.pdf

Assessment Name: Superior Mixed Forest
Ecoregions: NA0418. Superior Mixed Forest
http://conserveonline.org/coldocs/2003/05/SMF_Ecoregional_Plan.pdf

Assessment Name: Western Allegheny Plateau
Ecoregions: NA0420. Western Allegheny Plateau
http://conserveonline.org/workspaces/ohioriver/documents/western-allegheny-plateau-ecoregional-plan

Assessment Name: The Sweetwater Sea. An international biodiversity conservation strategy for Lake Huron. http://conserveonline.org/workspaces/lakehuron.bcs/documents/final-report-the-sweetwater-sea-an-international/view.html

Assessment Name: The beautiful lake: a binational biodiversity conservation strategy for Lake Ontario. http://www.epa.gov/greatlakes/lakeont/reports/lo_biodiversity.pdf

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