State of the Science:

An Assessment of Research on the Ecological Impacts of Wind Energy in the Great Lakes Region

Great Lakes Wind Collaborative

Great Lakes Commission November 2011

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Contents

Acknowledgement

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Wind Energy and the Environment

Wind energy has many environmental advantages over other conventional methods of energy production.[1] Despite these benefits, placement of large turbines across the landscape (or potentially in the water) can have negative ecological impacts. Some of these impacts are fairly well understood; they have been well studied or are known from past experience or research on similar practices. For example, we know that land clearing for constructing a wind farm causes habitat fragmentation and destruction, like many large-scale development projects. What is not fully understood is the ability of local flora and fauna to successfully repopulate the areas after the turbines have been installed. Wind farms occupy large areas of land, but unlike other large development projects, once construction is complete, the amount of land they actually take up is relatively small.

Numerous regional, national and international forums exist to support ecological research, including how different human activities impact species, their habitats and ecological functions. Several entities focus specifically on understanding the ecological impacts of wind energy development on wildlife including, but not limited to, the Wildlife Workgroup of the National Wind Coordinating Collaborative,[2] the American Wind Wildlife Institute[3] and the Bats and Wind Energy Collaborative.[4] Notwithstanding the value of these efforts, which are broad in geographic scope, it is

The ecological impacts of any given wind farm will depend largely on the ecological conditions of the site, the habitat present and species present. Knowing a species' range, its preferred habitat type, and its unique lifecycle habits, such as migration or hibernation patterns is essential to understanding whether external factors like wind turbines might alter or disturb those species. Species in the eastern Great Lakes region share more in common with the hilly deciduous forest habitats of the northeast, while those in the southwestern part of the Great Lakes region have more in common with the habitats of the Great Plains. The habitats and species the region shares most in common are those that are connected to the Great Lakes themselves: the terrestrial and aquatic habitats and species associated with the freshwater coast.

[1] Wind turbines do not use water whereas conventional energy plants use vast amounts of water for generating steam and for cooling. Wind as a fuel source is inexhaustible and readily available. Conventional power plants rely on fuel sources that require extraction and processing which causes varying, but often serious, environmental degradation. Moreover, wind energy produces no emissions while conventional energy production generate emissions that contribute to acid rain and snow, global climate change, smog, regional haze, mercury contamination, water quality contamination and particulate-related health effects.

[2] See www.nationalwind.org/issues/wildlife.aspx. This organization hosts a series of wind/wildlife research meetings dating back to 1994; see www.nationalwind.org/issues/wildlife/meetingproceedings.aspx.

[3] See www.awwi.org.

[4] See www.batsandwind.org.

critical to have regional and local focus to understand how wind development impacts the habitats and species in the setting where it is being proposed.

Workshop Goals:

- *Assess the current state of knowledge of wind energy impacts on the habitats and species of the Great Lakes region;*
- *Evaluate how we can apply what we know to improve decision-making; and*
- *Identify future research needs.*

Great Lakes Wind Collaborative State of the Science Workshop

An area of great interest and concern has been the potential negative impacts of wind farms on birds and bats. This same concern and interest extends to potential impacts of offshore wind farms on aquatic habitats and species. The need for a better understanding of wind energy impacts *in the Great Lakes region* provided the impetus for the Great Lakes Wind Collaborative to convene a *State of the Science Workshop on the Ecological Effects of Wind*.

The Great Lakes Wind Collaborative's 2011 *State of the Science Workshop on the Ecological Effects of Wind* was the first attempt to assess the current state of knowledge of wind energy impacts on the habitats and species of the Great Lakes region. The workshop further aimed to evaluate how we can apply what we know to improve decisionmaking and identify future research needs. Although a number of Great Lakes-specific studies have been conducted over the last several decades, there have been few opportunities to share that information at the regional level. [5]

The workshop took place on March 9-10, 2011, on the campus of Indiana University – Purdue University at Indianapolis (IUPUI) with more than 120 people in attendance. Participants represented state, provincial and federal governmental agencies, consulting firms, nongovernmental organizations (NGOs), academic institutions, electrical utilities and the wind industry.

Thirty oral or poster presentations were chosen based on their contribution to advancing the understanding of the impacts of wind energy on the ecological features and functions of the Great Lakes region.[6] The majority of presentations focused on scientific studies, either completed or underway. While most were Great Lakes-based studies, several studies from outside the region were selected based on their value to inform ecological impact studies and assessment in the Great Lakes region. The workshop goal of sharing research results and activities was not predicated on such research being complete or peer-reviewed.

This report describes current knowledge on the ecological impacts of wind energy in the Great Lakes region, both onshore and offshore, based on information presented at the 2011 GLWC *State of the*

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[5] An annotated bibliography reviewing the existing literature on effects of wind energy on wildlife in the region is available on the GLWC webpage at www.glc.org/energy/wind/. In addition, resources are available in Wiki format at http://wiki.glin.net/display/GLWCC/Effects+on+Wildlife.

[6] The Great Lakes region is comprised of the eight states and two provinces that border the Great Lakes.

Science Workshop. It includes information and ideas shared through formal presentations and posters as well as during discussions in workshop breakout groups.

State of Knowledge on Impacted Wildlife Groups and Habitats

Many presentations at the GLWC's *State of the Science Workshop on the Ecological Effects of Wind* provided results from studies and assessments. The information reviewed in these presentations is summarized below and divided into four sections: raptors, passerines and other birds, bats, and aquatic resources. Information on potential impacts to the habitats of these wildlife groups is also discussed.[7]

See the workshop presentations online at http://www.glc.org/energy/wind/sosworkshop/pdf/SOS-Presentations.pdf

Raptors

What We Know

Studies indicate that raptor fatalities at wind energy sites in the Great Lakes do occur *(1, 2)*. Of 86 active and proposed wind projects assessed in Pennsylvania, 41 present medium to high risk for raptor collision *(1)*. There is a major raptor migration corridor on Lake Superior's north shore, an area with high wind energy potential. Large numbers of raptors were observed using this corridor in fall 2008-2010, with numbers peaking four to six hours after sunrise *(3)*. Flight behavior in this part of the Great Lakes region indicates that the corridor for some migrating raptors is likely farther inland from shore than that of other birds *(3)*. Analysis of data from 1999-2009 suggests that fatality rates for raptors are similar at nearshore and inland sites across the Great Lakes *(2)*.

Although wind turbines pose a risk of fatality to raptors, overall these risks appear to be relatively low when compared to risks posed by wind energy to other types of birds. A 2006-2007 fall diurnal raptor migration study in Ontario showed negligible impact of a wind farm on raptor populations and the raptor migration corridor *(4)*. At eight wind farms monitored in Pennsylvania, raptor fatalities accounted for only 3 percent of total annual bird fatalities *(1)*. The explanation for this reduced risk to raptors is not entirely clear. However, studies on the northern shore of Lake Superior suggest that migrating raptors typically fly higher than the rotor swept zone (RSZ) of turbines, thereby reducing risk of collision (*3)*.

[7] As noted earlier, peer-review or other evaluation of the quality of the research was not a strict criterion for abstract acceptance. The primary goal was to share regionally-relevant data and information. As such, not all research summarized has been peer-reviewed. The Great Lakes Wind Collaborative does not endorse the individual studies presented. Rather, the GLWC urges readers to use this information as a starting point for further inquiry to build a more robust body of ecological knowledge that can inform wind energy development decisions.

Gaps and Research Needs

There are several gaps in our understanding of the potential impacts of wind energy on Great Lakes raptor populations. Studies should continue to be conducted at various locations in order to clarify why risk varies from site to site, which could inform mitigation measures and where turbines are sited. Migration corridors must be further studied and delineated. Another knowledge gap is the potential sub-lethal effects of wind energy development on raptor populations; for example, impacts on raptor habitat (e.g., feeding areas and winter habitats) and behavior are not well understood[8]. There is also uncertainty regarding potential impacts to raptors from offshore wind. Although case studies from Europe suggest that risks to raptors are minimal *(2)*, raptor use of offshore regions in the Great Lakes may differ and should be examined.

Passerines and Other Birds

What We Know

Studies presented at the *State of the Science Workshop* indicate that of all bird groups, passerines (or songbirds) are most likely to be impacted by wind energy in the Great Lakes region. Mortality rates for all birds at Great Lakes wind farms vary, but are generally low[9], with averages of 3.9 birds/turbine/year in Pennsylvania *(1)*, 2.5 birds/turbine/year in Ontario *(4),* 4.7 birds/turbine/year at a New York site *(2)*, and 11.8 birds/turbine/year at a Wisconsin site *(2)*. Passerines make up the largest proportion of these fatalities with up to 78 percent of all bird fatalities across the Great Lakes *(2)*.

Fatalities peak during spring and fall migration periods, with a larger peak in fall *(1, 5)*. Passerine fatalities are greater at nearshore than inland sites *(2)*, which may be due to their concentration near Great Lakes shorelines. One area where this is evident is the north shore of Lake Superior in Minnesota, with about 150 species identified and maximum numbers of more than 8,000 songbirds observed in two hours during fall 2008-2010 *(3)*. Of the 150 passerine species observed, more than 30 were of conservation priority. Most non-raptors using this migration corridor were observed flying within one kilometer of shore; numbers peaked about one to two hours after sunrise *(3)*. Large numbers of migrating passerines also use the Lake Erie coastline at several locations in the fall *(6)*. Passerines have been observed flying lower than raptors and other birds, making them more likely to overlap with the RSZ, which may explain their higher risk of mortality *(3)*.

Despite potential overlap in waterfowl habitat and wind farm siting, North American and European studies identify that offshore wind has a limited direct mortality impact on waterfowl populations (2). Large numbers of pelagic birds have been observed in offshore (25-30 miles) waters of Lake Erie, with

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[8]Drake, D. Response of Raptors to a Wisconsin Windfarm. Presented at the National Wind Coordinating Collaborative Wind Wildlife Research Meeting VIII. October 19-21, 2010. Lakewood, Colorado.

[9] While all birds are pooled into these generalized mortality percentages, ultimate effects of project-induced mortality rates on individual species depend on the species – less common or imperiled species may be more greatly affected by the same mortality rate that wouldn't have a measurable effect on a more common species. Although a single-turbine mortality rate may appear low, the actual mortality for a species across multiple turbines within a single project and across multiple projects represents the "true" mortality of wind projects on a species.

peak densities in fall and different species peaking at different distances from the shoreline *(18).* Seaducks have been recorded more than six miles from shore in Lake Erie *(17)*. Bird surveys in Lake Erie, including gulls, indicate that a majority of bird migration occurs at elevations higher than the RSZ, while some birds were also observed flying very close to the surface of the water but below the RSZ *(13)* which suggests that birds in Lake Erie may not typically fly at heights of the RSZ. However, additional research is needed to examine flight patterns under different weather and seasonal conditions to determine whether the RSZ is indeed an area that is not preferred, or could be avoided.

While the Great Lakes ecosystem is different from marine systems, much of what we know regarding potential impacts of offshore wind energy projects to birds comes from European studies in marine environments. While this work suggests that bird mortality due to collision with offshore wind turbines is relatively low, impacts are still possible. In addition to potential risks from offshore wind farms, over-wintering waterfowl populations may also be at risk from inland wind energy development *(2, 17, 19)*.

Gaps and Research Needs

Passerine species appear to be at greatest risk of fatality from collision with turbines during the spring and fall migration when they use nearshore areas; thus, it is important to enhance our understanding of migration patterns and behavior. Because most species of birds and bats migrate nocturnally, 24-hour migration studies are needed. *(6)*. In addition to identifying migration corridors and understanding temporal characteristics of passerine migration, specific characteristics such as rate of ascent and descent and use of islands should also be studied *(7)*. We also must improve our understanding of how wind energy development and other human-induced changes serve as barriers that can shift local migration movements, which has been documented in Europe *(2)*. The impacts of such forced adaptation remain unknown for passerine species in the Great Lakes region.

Moreover, the use of offshore Great Lakes areas by passerine birds is not well understood. Efforts are currently underway across the region to survey near- and offshore regions for passerine use *(8, 9)*. Passerines appear more likely to be impacted by offshore wind than raptors and other land birds *(2)*.

Support of ongoing work and additional studies on waterfowl migration behaviors and corridors is necessary to understand the potential ecological impacts of offshore wind development. In addition to direct mortality impacts, possible displacement along migration routes or between roosting and feeding areas is not currently well understood *(17)*.

Bats

What We Know

Studies presented at the workshop indicate that bats in the Great Lakes region, particularly migratory tree bats such as the hoary bat, eastern red bat and silver-haired bat are at risk of fatality from collision with wind turbines *(1, 2, 4, 5)*. Mortality rates are higher for adult male bats than juveniles and females *(1)*, and peak fatalities occur during the fall migration period *(1, 5)*. Of 86 active and proposed wind facilities assessed in Pennsylvania, 31 of these facilities represented high mortality risk to bats *(1)*. At eight wind energy facilities in Pennsylvania from 2007-2009, average bat mortality was 24.6 bats/turbine/year; migratory tree bats comprised 67 percent of overall mortality *(1)*. Of all bat fatalities at Midwest wind farms between 1996 and 2009, 42 percent were migratory tree bats *(5)*. Bat mortality at Ontario wind farms in 2010 ranged from two to 14 bats/turbine/year *(4)*.

Midwest	• 42% of bat fatalities were tree bats between 1996-2006
Pennsylvania	• 36% of the wind facilities assessed show a high mortality risk to bats • Average bat mortaility was 24.6 bats/turbine/year; 67% were tree bats
Ontario	• In 2010, bat mortality ranged from 2 to14 bats/turbine/year

A potential explanation for spatial variation in bat fatalities is level of bat activity, which appears to be correlated with mortality rate *(10)*. Landscape features, such as ridges or shorelines, may also influence bat activity and thus mortality rates. For instance, higher bat activity was documented along Ontario's Lake Huron shoreline as compared to other landscape features in the province *(11)*.

Offshore wind projects in the Great Lakes could also represent a fatality risk, primarily for migratory bats. Monitoring performed in the Gulf of Maine indicates that bats migrate and forage in near- and offshore areas *(12)*; similar behavior could occur in the Great Lakes. Studies indicate that migratory tree bat migration corridors may exist over coastal and offshore areas of the southern Great Lakes region *(12)*. Surveys in Lake Erie off Cleveland, however, suggest that offshore bat activity levels are significantly lower than onshore, and peak in mid- to late August *(13)*.

Gaps and Research Needs

While European studies show low rates of bat mortality at offshore wind sites *(2)*, it is unclear whether risks will be similar on the Great Lakes. Despite past and ongoing studies assessing the risk of wind development to bats in the Great Lakes region, many knowledge gaps remain. Migratory tree bats, during their fall migration period, appear to be at greatest risk from wind energy development; thus, continued research to document their migration behavior and corridors is vital *(1, 4, 7, 12)*. Habitat and landscape features important to bat migration must also be identified *(4)*. Relationships between bat activity and fatality could be elucidated; for example, it is unclear whether pre-construction bat activity is correlated with post-construction activity and whether bats are attracted to wind turbines (*10)*. The proximity of wind farms to bat hibernacula, the location elected by bats to hibernate, may also have an important link to collision risk *(1)*.

In order to enhance our understanding of potential impacts from offshore wind, survey methods tailored to the Great Lakes should be improved, as many existing protocols are designed for terrestrial systems or for offshore marine environments in the U.S and Europe *(2, 12)*. Other technical needs include better mortality estimators, replication of studies examining deterrent actions and curtailments such as cut-in speeds, and research pairing fatality searches and detectors *(1, 10)*. Another research priority is improved bat detection methods. Current methods assume equal detection across species and habitats, an unlikely assumption that can be avoided through the use of tools such as perceived occupancy models *(14)*. In addition, bat call libraries (an inventory of bat vocalizations, usually in electronic audio files, made available from a central distribution site for reference, research and information exchange) need to be expanded to inform effective detection and monitoring *(14)*.

Most of our knowledge of the impacts of wind energy on bats involves direct mortality due to collision; however, we also must improve our understanding of potential indirect and cumulative impacts of wind energy on bat populations over time. It is especially vital to examine cumulative effects on populations of high-risk migratory tree bat species. Research on cumulative impacts is particularly important in the face of threats such as white-nose syndrome that also have the potential to significantly impact bat populations *(4)*.

Aquatic resources

What We Know

There currently are no offshore wind farms in the Great Lakes, so potential ecological impacts must be extrapolated from completed studies on offshore turbines and other anthropogenic structures in marine environments. Review of existing offshore wind farms indicates that offshore wind development may impact fish and other aquatic resources via direct or indirect effects from habitat alteration, noise from construction and operation, and electromagnetic fields. Other potential impacts may appear in the lake hydrography and coastal morphology. Benthic habitat lost due to turbine installation is minimal (15, 16).

Construction of an offshore wind farm in Denmark temporarily displaced marine mammals through noise, vibration and changes to habitat *(15)*; wind development in the Great Lakes could result in similar displacement impacts to fish. European studies of potential cumulative impacts recommended that construction not take place during important reproductive stages for species of concern *(15)*. Pile driving noise occurring during construction could also impact fish through auditory tissue damage, startle and alarm response, and even fish kills *(16)*. Electromagnetic fields could impact fish by disorienting migration and prey and mate detection. Several Great Lakes species of conservation concern, including the American eel and the lake sturgeon, are particularly sensitive to electromagnetic fields *(16)*.

Offshore wind power generation within the Great Lakes has the potential to be implemented with minimal impacts on the aquatic ecosystem if mitigation options are adopted, benefits are enhanced, learning is built into the management cycle, precaution is taken as to site location, and appropriate baseline and effects monitoring are conducted (16).

Gaps and Research Needs

It is difficult to address knowledge gaps related to Great Lakes offshore wind power at the present time because there are no offshore wind projects yet deployed in the Great Lakes to study. For instance, while we can examine European facilities to better our understanding of the potential impacts of operational noise and electromagnetic fields, it is difficult to say with any certainty that these impacts will be analogous with those in the Great Lakes ecosystem since both environments are so different.

One of the more informative research gaps identified through the *State of the Science* workshop is the extent of injury or disturbance to nearby fish and benthic communities from construction noise. The magnitude of effects appears to be highly dependent on project location, construction timing and species-specific sensitivity to various types of disturbance. Research that can be conducted to fill some of the gaps pertaining to this issue include laboratory research to study sensitivity of Great Lakes fish species to noise and electromagnetic fields, studying the impacts of existing submarine transmission lines, predictive models of hydrodynamics, and field experiments to study how to enhance the benefits of artificial reefs.

It is also worth exploring potentially beneficial ecological impacts of offshore wind development in the Great Lakes. For example, artificial structures such as wind turbine foundations may create reef-like habitats that could benefit species such as lake trout (16). Offshore wind farms may also create habitat for aquatic invertebrate species; however, in the Great Lakes, invasive species such as dreissenid mussels and round gobies may benefit from additional hard substrate (15, 16).

Research Priorities

Due to the region's history and experience with siting land-based wind farms, there is a good understanding of what types of wildlife would most likely be affected by onshore wind projects, such as passerines and migratory bats. Still, numerous research gaps remain, particularly in the area of understanding how wind projects may potentially impact migratory bird behavior and migratory bird habitats. Comparatively, science on the ecological effects of offshore wind energy is still in its infancy. Due to the Great Lakes region's unique freshwater environment, results from marine studies are not directly transferable to this region.

Gaps in our understanding of the ecological impacts of wind energy can be addressed through the pursuit of research that addresses the following research priorities as identified at the *State of the Science Workshop*.

Great Lakes Research Priorities

1. *Wind development effects on migratory corridors and behaviors for raptors, passerines, waterfowl and bats*
2. *Common, adaptive survey and monitoring protocol*
3. *Ecologically defensible mortality thresholds and setbacks*
4. *Potential benefits from artificial reef habitat creation*

- Conduct research on migratory corridors and behaviors for raptors, passerines, waterfowl and bats with particular attention identifying and documenting:
    - 24 hour migration characteristics
    - Ascent and descent characteristics
    - The use and relative importance of islands and offshore areas
    - Potential direct and indirect impacts to migratory species, habitats and
    - Potential displacement between roosting and feeding habitats development.
- Development of consistent and/or standardized survey and monitoring protocols for the Great Lakes region.
- Update and develop of ecologically-defensible mortality thresholds and setbacks from significant habitat areas.[10]

[10]The U.S. Fish and Wildlife Service is working collaboratively with other wind energy stakeholders to address the ecological and population-level effects of wind development on migratory birds and bats. Nevertheless, the Migratory Bird Treaty Act and Endangered Species Act enable the enforcement of a take of these species (e.g., accidental killing or harming a listed species) which does not depend upon ecological effects or mortality thresholds.

- Evaluate the significance of various potential effects of offshore wind facilities on Great Lakes fish and other aquatic species.
  - Assess the habitat creation potential of wind turbine foundations in the Great Lakes
  - Quantify thresholds for physiological or behavioral effects of noise and electromagnetic fields for representative Great Lakes fish taxa
  - Identify areas used as spawning or nursery habitat, migration corridors etc. where development should be avoided

Table 1: State of the Science and Knowledge Gaps for the Great Lakes Region[11]

	State of the Science	Knowledge Gaps
Raptors	Migration corridors exist in Great Lakes region, but migratory impacts to raptors are low compared to other bird groups	Offshore impacts; cumulative population impacts
Passerines	Most at-risk bird group; highest fatalities in near shore region during spring and fall migrations	Specific migration characteristics (e.g., 24-hr patterns, flight height, rates of ascent and descent); cumulative population impacts
Other Birds	Potential indirect impacts (avoidance disturbance) to migrating waterfowl	Ecologically based migratory and habitat setbacks, defined migratory routes[12]
Bats	Migratory tree roosting bats at greatest risk; fatality rates can be high	Further documentation of migratory behaviors and routes; attraction potential of turbines; cumulative population impacts
Aquatic	Construction noise likely a temporary impact to aquatic species based on European studies	Construction noise impacts to nearby fish and benthic communities; Impacts of electromagnetic fields; Need to consider potential beneficial impacts

Science in the Context of Decision Making

Regulatory decisions for wind energy development, notably, permit applications for siting wind farms, require ecological data and information.[13] However, as noted above, research on ecological impacts from offshore wind in the Great Lakes is just beginning. At the GLWC *State of the Science Workshop,* participants heard about regulatory frameworks, guidelines for development to minimize ecological impacts, and models and assessment protocols to collect and synthesize more and better data that could help support regulatory decisions absent a robust body of completed research.

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[11] As identified at the Great Lakes Wind Collaborative State of the Science Workshop, March 9-10, 2011.

[12] Ontario's Significant Wildlife Habitat Technical Guide identifies species habitats and establish areas of setback protection (in addition to general 120m)

[13] Ontario's offshore wind permitting program requires ecological data and information as part of the permit review and approval process. Although there are currently no U.S. state offshore wind permitting programs for the Great Lakes, existing state rules for other purposes and proposed state rules and legislation that are designed to address offshore wind indicate that ecological information will be required to obtain state-level permits for leasing Great Lakes bottomlands. Additionally, the U.S. National Environmental Policy Act will require an Environmental Impact Statement or Environmental Assessment for any wind farm in the Great Lakes.

Siting and permitting of wind farms is often the greatest hurdle to the development of additional wind capacity. Completing required environmental assessments is time-consuming and expensive *(9)*. Assessment of impacts often lacks cross-impact benefit and cost comparisons, and adverse impacts tend to dominate the regulatory process (*20)*.

Setbacks and Acceptable Mortality Levels

Participants at the *State of the Science Workshop* identified the development of ecologically-defensible mortality thresholds and setbacks as an overarching priority need for the Great Lakes region. In some jurisdictions, such as Ontario, regulatory agencies currently impose mortality thresholds. Levels of acceptable mortality enforced in Ontario are 10 bats/turbine/year, 18 birds/turbine/year, and 0.2 raptors/turbine/year *(4)*. When these thresholds are exceeded, mandatory mitigation and/or monitoring is enforced. In the U.S. however, it is challenging to enforce such measures where there is no statewide permitting system for wind, either on land or offshore. In addition, acceptable take levels are particularly difficult to enforce if there are no fatalities of state or federally- listed bird or bat species[14] *(1)*. As discussed previously, take levels of bats in the U.S. often exceed the mortality thresholds imposed in Ontario although average mortality vary widely among sites *(1, 2)*.

It is difficult to determine whether these mortality thresholds are ecologically significant, given our lack of understanding of cumulative, population-level impacts of turbine-induced bird and bat mortality *(1)*. Properly-defined take levels are also likely to vary based upon species and geographic area. In Ontario, habitat is also protected from wind energy development through regulation. Pre-construction monitoring is required to locate Significant Wildlife Habitats (SWHs) for birds and bats, and wind farms must be developed with a setback of 120 meters from the outer edge of any SWH that is identified *(4)*. SWH for certain species may extend up to 1000 meters (in addition to the 120 meters). Again, however, questions remain as to whether setbacks such as this are biologically and ecologically relevant and accurate, and further research is needed to address these concerns.

Siting Guidelines

In the absence of regulatory setbacks and acceptable take levels in the U.S., some groups are producing voluntary guidelines to help developers reduce the ecological impacts of wind energy. Currently, the U.S. Fish and Wildlife Service (USFWS) has drafted Land-Based Wind Energy Guidelines and Eagle Conservation Plan Guidance *(8)*.[15] These documents recommend a tiered, risk-based approach based on location –specific ecological features and circumstances. The Nature Conservancy has conducted an extensive literature review and developed recommendations based on that literature review which can inform the development of guidelines to reduce the ecological impacts of wind energy in the Great Lakes. The Nature Conservancy's recommendations cover both siting (e.g., shoreline buffer distances) and the operations (e.g., intermittent lighting of turbines) of wind farms *(7)*.

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[14] The U.S. Fish and Wildlife Service has a statutory role with respect to take of migratory birds, i.e., the Migratory Bird Treaty Act is a strict liability law, enforcement of which does not depend on ecological or population level effects of take of migratory birds.

[15] See http://www.fws.gov/windenergy.

Although there is limited understanding of the potential impacts of offshore wind in the Great Lakes, recommended guidelines for its siting can be found by looking at European models. For example, Danish recommendations for protecting waterfowl include 1000 meter buffers around roosting sites and flight corridors *(17)*. In Ontario (Canada), SWH setback protections can extend up to 1000 meters from certain habitats (in addition to the standard 120 meters).

Monitoring

Appropriate assessments of the potential ecological impacts of wind development, particularly in areas deemed high-risk, often require pre- and post-construction monitoring. However, there is little standardization of the monitoring process within and across Great Lakes jurisdictions. In order to facilitate siting and permitting processes, there is a need for more consistent and/or standardized monitoring protocols in the Great Lakes region.

There are regulatory frameworks that can serve as models for standardized monitoring in the Great Lakes region. For example, in Rhode Island the Special Area Management Plan process, initiated under the state's Coastal Zone Management program, encourages the development and testing of standardized protocols for baseline studies and monitoring in areas of potential offshore wind development *(26)*. This framework requires pre-, during-, and post-construction monitoring that can include avian species, benthic ecology, and fish habitat, among other characteristics. Within the Great Lakes region, Pennsylvania's Wind Energy Voluntary Cooperative Agreement, which includes protocols for pre- and post-construction monitoring, can serve as a model for an effective way to standardize assessments *(1)*. The ecological monitoring activities through these agreements have led to changes in siting and mitigation actions. The Ontario Ministry of Natural Resources has a model regulatory framework that requires three years of post-construction bat and bird mortality monitoring at all wind power projects, and in some cases also requires habitat monitoring and operational mitigation *(4)*.

Decision-Support Tools and Frameworks

Tools are being developed to facilitate these regulatory processes and to focus assessment efforts in areas of greatest risk. Environment Canada and the Ontario Ministry of Natural Resources are conducting meta-analyses to identify areas of low collision risk, where wind development can proceed with minimal studies *(4, 9, 20)*. This work will also inform studies that should be conducted in higher-risk areas, such as migration corridors. In the U.S., federal scientists are developing an Environmental Risk Evaluation System which draws on datasets from laboratory studies and pilot and commercial offshore wind farms to evaluate the potential ecological impacts of offshore development *(21)*. Moreover, the U.S. Fish and Wildlife Service's efforts in identifying sensitive areas for migratory birds and bats (e.g., migration corridors, migration stop-over sites, etc.) will provide objective information to decisionmakers (8). Lessons can also be taken from the European experience, where planned development is facilitated by a coordinating agency, a model that minimizes project costs and development time and facilitates best practices for environmental assessment *(15).*

Some experts recommend an ecosystem services approach to assessment, a science-based and transparent process which is well suited to analyze cross-impact benefits and costs *(20)*. On a nationwide level in the U.S., researchers are developing an Environmental Protocol Framework tool – based on the analysis of existing models, methods, and outcomes from existing offshore assessment programs around the globe – that will inform regulatory agencies and project developers on the studies and protocols needed to move forward on offshore wind development *(22)*.

Other useful tools or models that could inform siting and decisionmaking include: integrated assessment, which evaluates the effects of wind energy development in ecological, social, and economic dimensions *(23)*; adaptive management, which is a process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood *(24)*; and Element Distribution Modeling, which uses environmental characteristics of known locations to inform siting across larger spatial scales given different stakeholder and conservation priorities *(25)*.

A common, adaptive survey and monitoring protocol should be designed to meet specific goals of individual states and ecoregions but have application for the larger Great Lakes basin ecosystem

Conclusions

Policy should be informed by sound science. However, at the present time, science and policy for offshore wind in the Great Lakes are progressing at distinctly different paces. The body of scientific literature about ecological impacts of wind energy is still relatively young. Great Lakes region-specific research, particularly as it relates to offshore wind, is notably lacking. Additional research and studies are needed to direct how wind projects are planned, sited and operated in the region. Answers are needed to questions such as: What are acceptable levels of take for a species? What are appropriate buffers from important ecological areas? How is “ecologically-defensible” determined?

The research needed to answer these questions will likely take years and possibly decades. Meanwhile, national, state and provincial policies supporting cleaner and more secure energy sources are encouraging the wind industry to move at a much more rapid pace. There is an urgent need at present for some type of standardized survey and monitoring protocols as part of a regulatory framework that can allow wind development to occur in ways that uses the best information available to minimize risks to sensitive species and habitats. The research presented at the *State of the Science Workshop* is a starting point to develop science-based protocols. Implementing such protocols through an adaptive management approach will allow wind energy development to continue using the best information available and enable new information to shape policy as it develops. Such a framework could meet present needs to protect ecologically sensitive features while allowing appropriate wind development to occur to achieve renewable energy goals.

A common, adaptive survey and monitoring protocol should be designed to meet specific goals of individual states and ecoregions, yet have application for the larger Great Lakes basin ecosystem to accommodate the ranges of the many species that cross jurisdictional borders, including migrating species. Making the best use of the information that is available will be critical. Providing new ecological data to the GLWC online wind atlas (http://erie.glin.net/wind) is one way to ensure that information is shared and available within the region. Another is by posting research and related articles through the GLWC wiki bibliography (http://wiki.glin.net/display/GLWCC/Wind+Energy+Bibliography). The Great Lakes Wind Collaborative will continue to support these activities and the work of its members to advance these regional priorities.

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