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Commentary

Research Priorities for Wind Energy and Migratory Wildlife

MARTIN D. PIORKOWSKI,[1] *Cornell Lab of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850, USA*
ANDREW J. FARNSWORTH, *Cornell Lab of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850, USA*
MICHAEL FRY, *American Bird Conservancy, 1731 Connecticut Ave, NW, 3rd Floor, Washington, DC 20009, USA*
RONALD W. ROHRBAUGH, *Cornell Lab of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850, USA*
JOHN W. FITZPATRICK, *Cornell Lab of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850, USA*
KENNETH V. ROSENBERG, *Cornell Lab of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850, USA*

ABSTRACT With upcoming global wind-energy build-out estimated in millions of units, cumulative environmental impacts must be considered and understood to promote responsible expansion of this renewable energy source. In June 2009, 30 wildlife scientists convened in Racine, Wisconsin, USA to identify key research priorities concerning wind energy's potential impacts on migratory wildlife (birds and bats). This working group suggested 4 areas where improved science is most needed to evaluate the impacts of wind-energy development on migrating animals more accurately than can be accomplished today: 1) standardized protocols and definitions; 2) new methods and models for assessing and forecasting risk; 3) documenting lethal and sub-lethal effects at existing wind facilities; and 4) improved facility-site access, data access, and data management for researchers. Focused research based on these priorities will both quantify potential risks associated with wind-energy development and help derive science-based, peer-reviewed, best-management practices for existing and future wind projects. © 2011 The Wildlife Society.

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The proliferation of wind-energy projects across the globe has raised concern about how wind-energy development in terrestrial and off-shore environments will affect resident and migratory wildlife (Desholm et al. 2006, Huppop et al. 2006, Arnett et al. 2008, Piorkowski and O'Connell 2010); however, this concern has not resulted in a proliferation of peer-reviewed literature (Kuvlesky et al. 2007) on impacts to wildlife populations. To date, most research has focused on assessing fatality rates at existing wind projects (see summaries: Erickson et al. 2001, Arnett et al. 2008), with only limited work on developing risk assessment models, protocols, and guidelines for siting of new wind facilities (Anderson et al. 1999, Kunz et al. 2007*a*, Bright et al. 2008, Desholm 2009). Furthermore, much of the existing research has been limited in geographic scale (e.g., single site or local area studies, Piorkowski and O'Connell 2010) and has lacked methodological standardization among sites (e.g., Osborn et al. 2000 vs. Johnson et al. 2002). A growing body of literature expresses: 1) the importance of more systematic and comparable data collection methods among sites (Anderson et al. 1999, Kerlinger and Hatch 2001, Allison et al. 2008), and 2) the need for quantitative assessments of the degree to which wind-energy development at various scales and within specific regions is detrimental to wildlife, especially migratory bird and bat populations (e.g., Kunz et al. 2007*b*, Arnett et al. 2008, Kerlinger et al. 2010).

To identify research priorities, the Cornell Lab of Ornithology, American Bird Conservancy, and The Johnson Foundation convened a facilitated workshop in Racine, Wisconsin, USA from 17 to 19 June 2009 entitled "Assessing Risks to Migratory Wildlife from Wind-Energy Development." Thirty scientists with backgrounds in industry, government, non-governmental organizations, and universities (see Appendix) discussed major issues and came to consensus on a small set of key research priorities. Goals of the workshop were to identify fundamental knowledge gaps in peer-reviewed research, define priorities to bridge these gaps, and identify steps for implementing appropriate research. Three of the invited participants to this workshop had co-authored a previous, peer-reviewed manuscript (Kunz et al. 2007*b*) that identified research needs specifically for bats. In this paper we describe the 4 primary research recommendations that we believe will help both regulators and the wind industry itself make informed decisions about priorities for future wind-energy projects that minimize impacts to all migratory wildlife.

Urgency in disseminating these research priorities to all stakeholders was amplified with the publication of the United States Fish and Wildlife Service (USFWS) Draft Land-based Wind Energy Guidelines (Guidelines; USFWS 2011*a*) and subsequent revisions (USFWS 2011*b*). These Guidelines evaluated the recommendations made by the

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[1]*E-mail: mp362@cornell.edu*

Wind Turbine Guidelines Advisory Committee (Wind Turbine Guidelines Advisory Committee 2010), established by the Secretary of the Interior under the Federal Advisory Committee Act, and have incorporated many of these recommendations into the current document (USFWS 2011*b*). The original draft Guidelines (USFWS 2011*a*) were available for public comment as announced by the Federal Register (Federal Register 2011, USFWS 2011*a*). These proposed Guidelines use a tiered approach and are organized as follows:

- Tier 1: Preliminary evaluation and screening of potential sites (landscape-scale screening of potential project sites).
- Tier 2: Site characterization (broad characterization of 1 or more potential project sites).
- Tier 3: Pre-construction monitoring and assessment (site-specific assessments at the proposed project site).
- Tier 4: Post-construction monitoring of effects (to evaluate fatalities and other effects).
- Tier 5: Research (to further evaluate direct and indirect effects, and assess how they may be addressed).

This tiered approach within the Guidelines emphasizes wind project risks to habitat fragmentation, habitat disturbance, and risks to resident wildlife. However, it does not adequately address risks to migratory wildlife and the geographical variation and concentration of migration populations in specific regions of North America. These are serious deficiencies, which should be expanded upon to better encompass risks to migrating birds and bats. We provide a detailed comparison of the recommendations resulting from the Racine workshop with those proposed in the current USFWS Guidelines (2011*b*). We echo the suggestion made by Kuvlesky et al. (2007) and propose that all stakeholders—agencies, scientists, industry, and the public—unify to implement the following research agenda, as the most constructive long-term solution to this emerging issue.

RESEARCH PRIORITIES

1) *Standardize methods and definitions used in pre- and post-construction studies focused on assessing impacts to birds and bats at wind facilities*. At present, comparisons of potential and real impacts across space and time at individual turbines and wind projects are extremely difficult because of variation in methods and metrics used (e.g., Johnson et al. 2002 vs. Kerns and Kerlinger 2004). We strongly recommend that all interested parties measuring impacts, adhere to standardized definitions of exposure risk, and follow uniform protocols for measuring risk in a Before-After-Control-Impact (BACI) design (Anderson et al. 1999, Kuvlesky et al. 2007). Moreover, assessing population-level impacts through objectively derived mortality estimates will be essential for understanding the big-picture effects of wind-energy development on birds and bats. For example, Smallwood et al. (2010) and Huso (2011) suggested that previous methods used to estimate loss of carcasses to scavengers do not provide accurate estimates of fatalities and likely underestimate total numbers of deaths. Major differences exist among protocols used at different project sites making it impossible to compare results meaningfully. This discrepancy especially limits our ability to model population-level effects across multiple spatial extents.

   The proposed Guidelines place emphasis on project-by-project assessments to determine whether adaptive management may be needed, but if these assessments are not standardized then meaningful comparisons cannot be made among project sites. As a result, Kuvlesky et al. (2007) suggest that localized assessments will not be useful for estimating potential impacts of wind installations across multiple spatial scales, from specific turbine locations (micro-siting) to placement of whole facilities across a state or throughout the hemisphere. Although the Guidelines acknowledged the importance of accumulating standardized data among multiple facilities, we also recommend stronger language in the Guidelines to ensure that these data are standardized and shared at all tiers in the process. Estimating cumulative impacts on migratory wildlife can only be accomplished via standardization of methodology. Standardization, in turn, requires much greater and more transparent cooperation among the industry and research communities than currently exists.
2) *Develop methods and models for assessing and forecasting risk to migrating birds and bats to inform pre-construction siting decisions*: Development of new analytic and modeling techniques to understand the relationships between spatial and temporal movement patterns of wildlife with respect to environmental and topographical factors is necessary to increase the predictive capabilities of forecast models, both within and among wind facilities. In particular, data on the 3-dimensional positions, identities, and behaviors of migrating animals garnered simultaneously from multiple sources (e.g., radar, acoustic monitoring, on-the-ground observations) are essential for assessing and predicting risk of impacts. Use of existing data sets such as those in the Avian Knowledge Network (www.avianknowledge.net) and the application of new and emerging technologies (e.g., automated acoustic monitoring) are encouraged to fill-in knowledge gaps of bird and bat distributions throughout their ranges. These mixed-modality assessments must be focused on fine-scale movements of animals in relation to key landscape features such as ridges, valleys, and coastlines. These assessments will be extremely important to micro-siting of specific turbines, as well as entire facilities, as siting will affect both wind-energy output and wildlife impacts. Quantifying the accuracies and uncertainties in these data sets will be paramount for making informed decisions, especially during the Guidelines' Tier 2 and Tier 3 assessments.

   Understanding movement characteristics of wildlife within the rotor-swept zone and around the physical supporting structures of wind turbines will help differentiate potentially hazardous sites from safer sites

(Smallwood and Thelander 2004, Smallwood et al. 2009). Identification of species, and sets of species, that are most at risk in regions of high wind energy will help evaluate the degree to which a site might be hazardous (Desholm 2009). Finally, risk factors need to be mapped geographically as isoclines, scoring the potential effects of proposed wind facilities on critically important migration and movement corridors according to a quantitatively derived risk index. The most important product from this work would be an overlay of industrially suitable wind resources mapped together with associated risk index scores. To this end, we urge the USFWS to adopt explicit definitions and explanations of the term "risk" within the context of the tiered approach. Mapping risk indices ought to be the ultimate goal for responsibly siting new facilities, or defining areas where more specific data need to be collected. Tiers 4 and 5 in the Guidelines speak to the validation of risk assessments, but not to the improvement of future risk assessments or potential forecasting that could be employed during the Tier 2 stage. Understanding and filling current gaps in knowledge, and informing existing models, are critically important precursors to assessing risk accurately. Pre-construction decision-making will benefit from improved risk assessment modeling at the earliest stages of a proposed wind installation.

3) *Document the lethal and sub-lethal effects of existing wind facilities on migrating wildlife to assess population-level impacts and validate forecasting models*: Assessing risk at wind facilities is fundamentally an empirical science. Progress in spatial modeling and in adaptively improving siting, design, and operations can only be made by measuring actual impacts, at real places. For this reason, standardized post-construction measurements (recommended in Tier 4 of the Guidelines) are absolutely essential. We emphasize the urgency of such studies using agreed-upon protocols that are implemented uniformly at all wind facilities. Understanding the biology underlying both lethal and sub-lethal interactions will help clarify the mechanisms and variables most associated with wildlife mortality at wind installations. Such data are vital for ground-truthing risk-factor mapping scores, thereby progressively increasing the power of pre-construction forecast models. Development, application, and integration of automated, real-time hardware, software, and algorithms to measure and map bird and bat movement through the rotor-swept area are especially important. We recommend that a minimum of 3 years of post-construction research, as suggested by Smallwood and Thelander (2004), be focused first at facilities in regions of greatest predicted risk to migrating birds and bats (e.g., Isthmus of Tehauntepec, Mexico; Great Lakes and Gulf Coast regions (Kuvlesky et al. 2007), United States; Straits of Gibraltar), and secondarily in high-migration areas where post-construction information is lacking. A similar duration of pre-construction assessment would be needed to statistically account for the same temporal variation in breeding populations and migratory species abundance, composition, and habitat use of particular sites or regions. The standardization of these study durations will inform and validate pre-construction risk assessments, and can further elucidate factors such as the Barrier Effect (an effect of birds altering their migratory flyways or local flight paths to avoid wind farms, Drewitt and Langston 2006) in the Tier 4 stage of the Guidelines.

   Standardized comparisons of predicted risk forecasts with post-construction impacts will inform development of fair criteria for mitigation measures and adaptive management. Nowhere has measuring the effects of mitigation for breeding and winter resident birds been more thoroughly tested than at the Altamont Pass Wind Resource Area (APWRA; Young et al. 2003, Smallwood and Thelander 2004, Smallwood et al. 2009). Measurements specific to resident and migratory bats have been conducted in Alberta, Canada (Baerwald et al. 2009) and Pennsylvania, USA (Arnett et al. 2010). However, measuring species density and abundance alone may not accurately predict high risk (de Lucas et al. 2008, Smallwood et al. 2009). Species-specific behaviors should be included to improve the accuracy of risk assessments (de Lucas et al. 2008, Desholm 2009).

   Drewitt and Langston (2006) describe 2 broad categories of mitigation, best-practice measures and site-specific mitigation that could be adopted as a site management plan. Examples within the APWRA of best-practice measures that have proved successful in mitigating avian mortality were development of taller, tubular towers for the mounting of nacelles and turbine blades, ceasing rodent control programs in the vicinity of active turbines, and removal of broken and/or non-operating turbines (Smallwood and Thelander 2004). Examples of site-specific mitigation conducted at the Tier 5 stage are referenced in the Guidelines, such as increased cut-in speeds (lowest wind speed at which a turbine generates power to the utility system, Arnett et al. 2010), and can be incorporated at other wind facilities. Such measures have been shown to substantially reduce bat fatalities (Baerwald et al. 2009, Arnett et al. 2010), often with minimal loss of power generation. Therefore, short-term curtailment of turbine operations during peak migration and/or high-risk weather conditions should be a component of adaptive management for projects built in high risk locations. Other mitigation strategies have been inconclusive or unsuccessful (e.g., ultraviolet paint on turbine blades, Young et al. 2003; industrial application of lab-tested motion-smear painting schemes, Hodos 2003). Post-construction mitigation could help alleviate negative effects in turbine micro-siting or operation not successfully identified in pre-construction research (Anderson et al. 1999, Horn et al. 2008, Arnett et al. 2010). Nevertheless, the overarching point is that objective, peer-reviewed assessments are essential in understanding the effectiveness of any mitigation strategy that may be developed in the Guidelines' Tier 5 research.

4) *Improve facility-site access, data access, and data management for researchers*: An enormous and ongoing obstacle

for meaningful, coordinated research has been limited access to constructed wind facilities to test research protocols and measure impacts (Kunz et al. 2007*b*). The science of measuring impacts of wind energy simply demands much greater cooperation and trust among industry and research communities to improve operating wind-project access, where standardized research is most needed. Equally important, data on both pre- and post-construction effects generally have not been shared with the at-large scientific research community or via publicly available databases, let alone through peer-reviewed outlets because of confidentiality concerns. We cannot emphasize this point strongly enough: data on impacts of existing, operating wind installations simply should not be proprietary, as comparing these data within and across sites are absolutely vital for understanding how industry can improve siting and operating practices over the long-term. Industries should not need to sequester post-construction data, as they have already concluded their site evaluation and construction (which understandably could include proprietary information). Open access to data and opportunities to share data among research teams for comparative studies would increase our overall knowledge of wildlife use, movement, and risk around wind facilities to such a large extent that this ought to be a major priority for all stakeholders.

A viable wind industry demands that the research community define how scientifically useful information can be disseminated in appropriate peer-reviewed publications and the popular media, while still respecting commercially proprietary concerns. Solving this problem will be essential for gaining and maintaining good-faith access to wind facilities. Some programs already do support alternative energy production through both compliance and voluntary processes (e.g., Renewable Energy Certificates, Holt and Bird 2005), and wind industry can be viewed positively in popular media as a conservation-minded energy industry through the use and participation of programs like Renewable Energy Certificates. In addition, third-party or umbrella organizations such as American Wind Wildlife Institute can play a key role in negotiating data sharing agreements between industry and the scientific community, a suggested idea to open access to data collected at these sites (Kuvlesky et al. 2007). At present, the Guidelines provide no solution for this hurdle, but resolving the impasse is imperative for addressing the large-scale question of cumulative wind-related impacts on wildlife, a concern raised over a decade ago by Anderson et al. (1999).

Indeed, the Guidelines obfuscate the issue of data access by stating that information gathered in the site evaluation process (Tier 1) is "confidential business information for the developer during this time when competitive issues limit developers' willingness to share information." We strongly recommend that biological data and analyses from both pre- and post-construction research (Tiers 2–5) be required at all wind installations, and that these data be shared more openly, including in the peer-reviewed literature. Developing scientifically valid best practices for wind-energy development clearly has emerged as a global public priority. This can only be accomplished if industry, agencies, and scientists cooperate in the process.

CONCLUSIONS

As stated in the Federal Register announcement, the USFWS acknowledges current wildlife protection statutes such as the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act, as well as its charge to uphold and implement these legal mandates. Nevertheless, their enforcement in relation to documented fatalities at wind facilities remains minimal. Smallwood and Thelander (2008) urge both the public and government agencies to provide greater clarity regarding enforcement of existing laws intended to protect species killed or wounded at wind facilities. Moreover, these research priorities target 4 of the major hurdles needed in order to effectively address how wind resource development may impact our environment and includes: 1) standardized protocols and definitions; 2) new methods and models for assessing and forecasting risk; 3) documenting lethal and sub-lethal effects at existing wind facilities; and 4) improved facility-site access, data access, and data management for researchers.

The priorities described above build on a growing body of research being conducted at existing and emerging wind projects across the United States and other parts of the world. Although these priorities highlight the utility of pre-construction risk assessment to inform siting decisions, workshop participants emphasized the critical importance of accurate and standardized post-construction measurements of actual wildlife impacts. In short, we cannot understand the real impacts of wind-energy development on wildlife until we develop credible risk assessment protocols through scientific peer-evaluation, construct facilities, measure fatalities in standardized ways, and continue to monitor impacts and refine aforementioned risk models with standardized protocols. Instituting measures to increase access to potential and existing sites and the availability of data, without jeopardizing industry production or profits, will be key to ensuring that decisions and policies regarding wind-energy development are based on the best available, peer-reviewed science.

Developing an open and honest partnership among industry, government, non-government, and academic scientists is the most important next step in implementing this research agenda. Rapid expansion of wind-energy infrastructure across the globe risks outpacing any research agenda, no matter how logical. Standardizing our approach to studying this issue, based on the research agenda outlined here, is essential now. Backing by the scientific community and an informed public is important for responsible development of alternative energy resources to meet our national and global energy goals. Failing to properly study and address potential impacts to wildlife, including the spectacle of migratory birds and bats, could result in weakened support and even societal backlash. In the words of one Racine workshop participant:

Imagine if a similar effort had taken place at the turn of the 20th century with the auto industry and air quality. We would probably be in a completely different place when it comes to global climate change and energy dependence, because we considered environmental impact from the start. (Kraig Butrum, American Wind Wildlife Institute).

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Appendix. List of participants invited and attending the "Assessing Risks to Migratory Wildlife from Wind-Energy Development" workshop in Racine, Wisconsin, USA.

Name	Affiliation	Name	Affiliation
Richard Anderson	California Energy Commission	Peter Frumhoff	Union of Concerned Scientists
Edward Arnett (invited)	Bat Conservation International	Michael Fry	American Bird Conservancy
Bart Ballard	Caesar Kleberg Wildlife Research Institute (Texas A&M)	Sidney Gauthreaux	Clemson University
Peter Bloom	Bloom Biological, Inc.	Douglas Johnson	USGS Northern Prairie Wildlife Research Institute (Univ. of Minnesota)
Rene Braud (invited)	Horizon Wind Energy	Imogene Johnson	The Johnson Foundation
Lynn Broaddus	The Johnson Foundation	Thomas Kunz	Boston University
Michael Burger	Audubon New York	George Ledec	The World Bank
Kraig Butrum	American Wind Wildlife Institute	David Mizrahi	New Jersey Audubon Society
Christopher Clark	Cornell Lab of Ornithology	David Pashley	American Bird Conservancy
Noel Cutright	WE Energies	Martin Piorkowski	Cornell Lab of Ornithology
Mark Desholm	National Environmental Research Institute (Univ. of Aarhus)	David Redell	Wisconsin Dept. of Natural Resources
Robert Diehl	University of Southern Mississippi	Kenneth Rosenberg	Cornell Lab of Ornithology
John Ehrmann	Meridian Insititute	David Stout	U. S. Fish and Wildlife Service
William Evans	Old Bird, Inc.	Dale Strickland	Western EcoSystems Technology, Inc.
Andrew Farnsworth	Cornell Lab of Ornithology	Genevieve Thompson	Audubon Dakota & American Wind Wildlife Institute
John Fitzpatrick	Cornell Lab of Ornithology	Rafael Villegas Patraca	Instituto de Ecologia AC