

# Wind Wildlife Research Meeting VIII

## Meeting Proceedings

October 19-21, 2010  
Lakewood, Colorado





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## **MEETING PROCEEDINGS**

**October 19-21, 2010**

**Lakewood, Colorado**

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## **Abstract**

Wind energy is able to generate electricity without many of the environmental impacts (conventional and toxic air pollution and greenhouse gases, water use and pollution, and habitat destruction) associated with other energy sources. This can significantly benefit birds, bats, and many other plant and animal species. However, the direct and indirect local impacts of wind plants on birds and bats continue to be an issue. The populations of many bird and bat species are experiencing long-term declines, due to the effects of a wide range of human activities, including energy production and consumption. These proceedings document current research pertaining to wildlife fatalities; habitat and behavioral impacts; cumulative and landscape-scale impacts to species; mitigation techniques and technologies; and offshore considerations.

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## **Ordering Information**

These Proceedings are available in PDF format with accompanying presentations available as separate pdf files. Proceedings may be downloaded from the NWCC website: [www.nationalwind.org](http://www.nationalwind.org)

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# Session 1. Welcome and Setting the Stage

## Welcome

### Abby Arnold, Kearns & West, NWCC Staff

This is the eighth Wind Wildlife Research Meeting since the National Wind Coordinating Collaborative (NWCC) convened its first research meeting in Lakewood, Colorado, in 1994. There were fewer than 50 participants at the 1994 meeting and a lot of questions. Sixteen years later, this room is full to capacity with 350 wind developers, environmental groups, biologists, state and federal agency staff, and consultants gathered to share the most recent and the best information available about wind-wildlife interactions.

Since 1994, we have moved from simply posing questions to answering some of them. This work has allowed, among other things, the U.S. Fish and Wildlife Service (FWS) to convene a [Federal Advisory Committee](#) and recommend guidelines for siting wind turbines. (See box for a brief timeline of collaborative wind-wildlife research efforts.)

#### Wind-Wildlife Research: a History

1994 – Might there be a better way to resolve the wildlife issues raised by wind energy development? Forty-four stakeholders came up with 49 technical questions.

1995 – Series of white papers published: how do we address these issues constructively?

NWCC became a resource to the National Renewable Energy Lab (NREL) in setting up a research program to begin answering questions raised at the research meeting.

1998 – [Studying Wind Energy/Bird Interactions: A Guidance Document](#) published to encourage and support greater consistency, rigor, and comparability of wind-wildlife studies at different projects.

2000 – Invited experts from other fields to look at different technology to answer wind-wildlife questions.

2004 – Our collective research has advanced to the point where we are able to pose the question: “Is Altamont unique?”

2006 – We reached the point where we could begin to do some combined analyses on data from multiple studies.

2008 – [Bats and Wind Energy Cooperative](#) (BWEC) had formed, and we started to look at shrub-steppe/grassland birds.

2010 – USFWS Wind Turbine Guidelines Advisory Committee came to a [consensus agreement](#) on a set of recommendations and submitted them to the Secretary of the Interior.

### **Acknowledgments**

The work of the NWCC is conducted by volunteers. Staff (Abby Arnold from Kearns & West, Lauren Flinn and James Damon from RESOLVE) facilitate the discussions, but the **Planning Committee** (see p. iii) was responsible for deciding what presentations and posters to accept. We received 73 abstract submissions, of which we were able to accept about half, relying on detailed scoring by an expert review panel. The Planning Committee met twice by phone to decide on which presentations and posters to accept, and the high quantity and quality of the work submitted made those decisions difficult.

We would also like to acknowledge the U.S. Department of Energy (DOE) for their support and the longer list of volunteers who have contributed to the NWCC's work over the past 16 years.

DOE has supported the work of the NWCC since its inception. To open this conference, we have asked DOE Environmental and Policy Specialist Patrick Gilman to invite people who are part of policy development for their respective organizations to frame the context for how the research we will be hearing presented is being used. The issues around wind-wildlife policy are richer, fuller, more complex, and more controversial than ever, so the question is how research is going to inform the policy decisions.

## **Setting the Stage – Panel Discussion**

### **Moderator: Patrick Gilman, U.S. Department of Energy**

The Department of Energy (DOE) has two roles with respect to wind-wildlife interactions. First, the DOE Wind Program conducts hard-core technology research and development work; our goal is to make wind technology as efficient and cost-effective as possible. Second, we do what we can to ensure that wind energy is deployed effectively and sustainably. Wildlife issues have been at the heart of this aspect of our work for over 16 years. The challenge is to “thread the needle” of risks wind technology poses to wildlife and habitat – to avoid those risks while developing wind energy on the scale needed to achieve the clean air and greenhouse gas reduction benefits that wind energy can provide.

We have asked our panelists to set the stage for the next couple of days by framing the questions we are asking the research community to help us answer, so that agencies responsible for protecting wildlife can meet their mandates as wind energy is developed in a timely manner on a scale that will address the climate issues.

### **Panelists**

- Albert Manville, U.S. Fish and Wildlife Service
- Michael Herder, Bureau of Land Management
- John Anderson, American Wind Energy Association
- Tracey Librandi Mumma, Pennsylvania Game Commission
- Genevieve Thompson, Audubon

Albert Manville, U.S. Fish & Wildlife Service

[Link to Presentation](#)

From the perspective of the Federal agency charged with wildlife and habitat protection, FWS sees needs for research, coordination, and communication that will allow us to better determine the direct, indirect, and cumulative impacts to wildlife and their habitats from commercial wind development.

***Most Pressing Issues and Roadblocks Regarding Wind Development***

Of these needs, the most pressing research topics and needs include:

- The need to better determine the direct, indirect, and cumulative impacts to wildlife from commercial wind development;
- Selecting the most wildlife- and habitat-friendly sites;
- Collision and possible population impacts to listed and sensitive species and Birds of Conservation Concern, including impacts to Whooping Cranes, California Condors, Golden Eagles, Bald Eagles, bats, and other imperiled bird/bat species;
- Habitat fragmentation, disturbance, site avoidance, and barrier effects that impact, among others, Prairie Chickens, Sage-grouse and grassland-sage-steppe-obligate songbirds, Golden Eagles, and Bald Eagles;
- Early coordination with the FWS including data sharing with FWS by the industry;
- Determining the cumulative impacts from individual turbines, individual projects, all land-based wind development continent-wide, and all anthropocentric impacts – projected into the future for the lifetime of all projects; and
- Assessing whether impacts become additive to “natural” compensatory mortality.

***What is Needed Regarding Wildlife Risk and Wind Development***

With respect to assessing wildlife risk and performing wind development research that will help us better address these issues and questions, we need:

- Better coordination with the FWS – beginning at the [Wind Federal Advisory Committee-recommended] Tier 1 stage;
- A willingness to work with the FWS to develop wildlife- and habitat-friendly wind sites including collaboration developing scientific rigorous Avian and Bat Protection Plans (ABPPs), collaboration on development and use of research protocols, and related efforts;
- Systematic evaluation of the temporal and spatial components of airspace as a habitat;
- Development of “tools” early on in the site assessment process to better determine risk – including, for example, finishing funding and implementing the U.S. Geological Survey’s Rapid Assessment Methodology being developed for use by the FWS, and development of a decision tree/matrix for performing pre- and post-construction monitoring;
- Rigorous scientific validation to determine whether blade “feathering,” seasonal shutdowns, changes in cut-in speed, turbine set-backs, use of pylons, infra- and ultrasonic deterrents, and any other “tools” actually work; and
- Better determination of risk and alignment of research protocols to ensure that pre- and post-construction studies are conducted at the appropriate scientific duration and intensity using valid scientific research protocols.

### ***Agencies Working Together***

In addition to the industry coordinating and collaborating with the FWS, it is critical that FWS and other State and Federal agencies work together. Presently, the following characteristics regarding agency collaboration are occurring:

- The FWS works with other Federal agencies where a Federal nexus applies – e.g., where there is NEPA review and Section 7 consultation through the Endangered Species Act.
- The FWS has and continues to coordinate with the U.S. Forest Service, the National Park Service, the Bureau of Indian Affairs and the Tribes, the Department of Energy, the Army Corps of Engineers the U.S. Marine Corps, the Department of Defense, and others. These collaborative efforts include FWS review of wind research protocols, assessment of projects and risk models, and suggesting efforts to “avoid or minimize take.” These include efforts through Executive Order 13186 (i.e., the Migratory Bird EO).
- Memoranda of Understanding (MOUs) under EO 13186 that have already been signed include those with the Department of Defense, the Department of Energy, the U.S. Forest Service, the former Minerals Management Service [renamed Bureau of Ocean Energy Management, Regulation and Enforcement], the Bureau of Land Management (BLM), and the National Park Service (NPS). The NPS MOU is an excellent model. All signed MOUs can be found on the FWS website. MOUs with the Federal Energy Regulatory Commission, USDA Wildlife Services, and the Federal Emergency Management Agency are under a final review process.
- Some U.S. agencies are more responsive in working with FWS than are others. The siting of wind projects will vary depending on the agency involved.
- FWS also works with representatives of the Canadian and Mexican governments to better coordinate and address wind-wildlife issues through the trilateral meetings of the Migratory Bird Table, under the auspice of the North American Free Trade Agreement.

### ***Wildlife Concerns from Wind Related to Wildlife Concerns from Other Land Development***

The Service has some concerns about comparing one source of anthropogenic mortality to another. For example:

- Comparing direct and growing impacts of wind (mortality currently estimated at 58,000-440,000 birds killed/yr. based on 23,000 turbines [Manville 2009]) to other sources of anthropogenic mortality is not especially helpful since the overarching issues are about cumulative impacts.
- While power line electrocutions are estimated to kill fewer birds per year than are wind turbines (Manville 2009), the Service focuses on addressing this electrocution issue since we have scientifically validated Suggested Practices (e.g., APLIC 2006) available to address electrocution “take.” We presently lack similar best management practices for wind development except through proper site location.
- There is ongoing concern over the large and growing footprint of wind development and its fragmentation, disturbance, site avoidance, and barrier effects, and our ability to verify cause and effect. The collective impacts of oil and gas, mountaintop mining, building windows, cats, power lines, communication towers, and other sources all add to the cumulative impacts to birds, bats, and other wildlife.

All of these issues present huge challenges, especially since we still know so little about the impacts of commercial wind development on trust resources and their habitats. That, however, is changing – and we applaud those companies, their consultants, and those agencies working with the Service to better understand and address the wind-wildlife interactions.

### Michael Herder, Bureau of Land Management

Al Manville outlined the main issues (see above). The BLM receives applications for wind resource testing and for proposed project development on public lands. Wind energy projects are processed in our local offices (District or Field Offices) as applications for rights-of-way (ROW). Our biggest challenge as an agency is to ensure that we are consistent in the way we develop and apply monitoring and mitigation requirements across District and Field Office boundaries. Currently our field offices vary considerably in terms of what pre-construction surveys they require and in how the results of pre-construction surveys are used to define requirements for post-construction monitoring and mitigation.

A national Wind Energy Programmatic Environmental Impact Study (PEIS) was completed in 2006. That PEIS gave us Best Management Practices (BMPs) that guide our efforts in processing wind energy ROW applications. For the most part, BMPs have been very useful in addressing wildlife issues associated with wind energy projects. Unfortunately, a few BMPs are somewhat ambiguous and could benefit from clarification. The challenge for the BLM is in applying those BMPs consistently across District and Field Office boundaries.

Another challenge we face is the availability of current land use plans that describe what areas of public lands are available for renewable energy development and which are not due to the presence of sensitive resources. Many of our land use plans are not current and are in various stages of amendment or revision. These changes to our land use plans will reflect the focus on renewable energy.

The BLM continues to work cooperatively with our federal and state agency partners in seeking solutions to our common issues related to wildlife impacts at wind energy facilities.

The BLM's future needs will focus on methods to develop meaningful mortality thresholds that trigger "significance" from a National Environmental Protection Act (NEPA) perspective. We need better information about the effectiveness of deterrence and early warning methods and devices, as well as the effectiveness of various mitigation methods. We will continue to work to build better and more effective partnerships between our agency and wind energy developers.

### John Anderson, American Wind Energy Association

From the wind industry's perspective and a non-wildlife standpoint, one of the most pressing issues we face is the lack of federal policy with regard to renewable energy standards and incentives. Less demand and lower prices for energy in the short term are making it difficult to develop this resource.

Publication of the Federal guidelines for siting with respect to wind and wildlife would be helpful. We need a better understanding of Bald and Golden Eagles, Indiana bats, Sage-grouse and Prairie Chickens (among many species), and we need more research to understand the risks and potential threats to those species. The effectiveness of proposed mitigation strategies also needs to be supported with hard science. It's hard to use a multimillion dollar project as an experiment to test some of these strategies when the banks that finance those projects are looking for certainty.

Our opinion is that we have done more than most industries to collaborate and partner with state and federal agencies. At the same time, the agencies need to understand what the industry faces –

particularly in terms of how the timing and uncertainty of the permit process affect industry's ability to obtain financing.

From an industry perspective, there still is not a lot of intra- and inter-agency coordination, although this has improved over the past few years.

Direct impacts from wind – dead birds on the ground – are visible and more easily traced to the source of mortality. However, impacts from coal, for example, are harder to point to in the same way – yet they are pervasive: from extraction and transportation of the fossil fuel to its combustion and disposal of waste products, etc. and therefore more impactful to wildlife as a result. From the wind industry's perspective, it is important to put what we're doing in context of other human activity.

### Tracey Librandi Mumma, Pennsylvania Game Commission

In the Commonwealth of Pennsylvania, not all of our natural resource agencies are under one umbrella. The Pennsylvania Game Commission (PGC) has jurisdiction over birds and mammals. We work with the Pennsylvania Fish and Boat Commission and other agencies such as the Pennsylvania Department of Conservation and Natural Resources, U.S. Fish and Wildlife Service, and the Pennsylvania Department of Environmental Protection.

PGC came up with a Wind Energy Voluntary Cooperative Agreement that went into effect in April 2007. Twenty-nine wind developers have signed the agreement, agreeing to one year of pre-construction and two years of post-construction monitoring. During the first year of the agreement, from the surveys conducted per the agreement, the 2nd largest Indiana bat maternity colony and the first lactating silver-haired bat were discovered in Pennsylvania. Currently, many sites are conducting various pre-construction bird and mammal surveys and a few sites are conducting post-construction mortality surveys. Thanks to these developers, we are getting a lot of data, and working on a report that we can publically share.

We are trying to use these findings to learn about impacts to birds and mammals from wind energy development. To date we have not had any threatened or endangered bats killed in Pennsylvania. However, we need to determine how far away from bat hibernacula wind sites should be located to minimize impacts to bats.

Bird mortality at Pennsylvania sites is pretty low, but some state-listed birds have been killed, so we have been working on creating a policy to address that. We also need more research to help us understand whether and when feathering/ curtailment are appropriate to minimize mortality.

Likewise, more information is needed on the cumulative effects on wildlife of the entire network of wind facilities across the country and where the right locations to encourage wind development are.

### Genevieve Thompson, Audubon

[Link to presentation](#)

Audubon strongly supports properly-sited wind power as a renewable energy resource that reduces the threat of global warming. As a partner in the Avian Wind Wildlife Institute (AWWI), Audubon collaborates with industry, agencies, and other NGOs to conduct research, create landscape assessment

tools, identify effective mitigation strategies, and conduct public outreach and education on the need for timely and responsible development of wind energy resources while protecting wildlife and habitat. Audubon also works with other collaborative groups such as the FWS, FAC, and the NWCC, and is active in the compilation of data and information relevant to avian protection: e.g., identification of Important Bird Areas (IBAs), State of the Birds report, and the Christmas Bird Counts.

The stakes are high, as both climate change and direct and indirect threats to species and habitat are real and immediate. At the same time, it is important to keep in mind that wildlife and habitat concerns and regulations are only one of many hurdles the wind industry faces when it comes to siting wind energy facilities (reference slide developed by Kenny Stein of FPL, illustrating hurdles to wind development).

The FWS FAC recommendations point to the need for applied research to address such challenges as:

- Insufficient information about population level impacts and effective mitigation measures
- A lack of coordinated planning and policy framework at all levels
- The need for better understanding of both direct strikes/collisions, and habitat fragmentation and “Species of Habitat Fragmentation Concern”

### ***Opportunities/Next Steps:***

Perhaps the biggest challenge is that the United States does not have a policy framework at the federal level. Absent a national energy bill that includes renewable energy standards, the issuance of National Wind Siting Guidelines is a critical next step that will drive the necessary wind-related research:

“... FAC recognizes and encourages the wind energy industry’s participation and support of partnerships such as AWWI, NWCC ... to promote needed research about wildlife and wind energy interactions.

The work that is shared at this conference is fundamentally important. It is not enough just to research *what* the risks are, but to conduct research that elucidates *how we mitigate* those risks. Collaboration is essential to applied research – to making a difference on the ground.

## Questions & Discussion

### ***How can we justify mitigation measures with hard science if developers are reluctant to use their projects as laboratories?***

Anderson: That’s the million dollar question. From the developer’s perspective, the greatest fear is that by allowing research and sharing data we will open ourselves up to liability under the Migratory Bird Treaty Act (MBTA). Developers need assurance that, as a cooperator, data shared will not be used against them. Also, we want to make sure that one season of study in one location does not result in a measure being applied nation-wide to all projects.

Thompson: We’re starting a pilot now with industry collaborators where we’re looking at how data can be shared; how the research gets done while ensuring that the parties and their proprietary data are protected. There is an adaptive management element to our approach.

Manville: FWS does recognize the concern. However, the Avian Power Line Interaction Committee (APLIC) model is worth considering. Here, there are more than 33 electric utilities voluntarily reporting bird deaths from power line collisions and electrocutions to a confidential FWS Law Enforcement database, with no prosecutions resulting from that reporting. The reporting helps address incident-specific issues and is Freedom of Information Act (FOIA)-protected.

***We've heard about the need to consider impacts of climate change. From the federal agency perspective, how is that being taken that into account?***

Manville: Within the Service's Division of Migratory Bird Management (DMBM), we are looking at the impacts of climate change on migratory birds. There is a Service team tasked to begin addressing the myriad impacts from climate change. DMBM is a member of this team and I am one of their representatives, but not our lead. How and when our assessments and recommendations will transition into policy remains uncertain.

Herder: BLM is participating in the development of policy to incorporate climate change concerns into the NEPA process. This effort has not yet resulted in policy or guidelines, but we are working on it.

***Should there be standardized policy for dealing with cumulative impacts?***

Manville: With ongoing staff and funding cuts – including an immediate 20% cut in all travel – are making it difficult to address this kind of analysis. However, a meta-analysis review of wind development impacts on migratory birds in Europe, published by the University of Birmingham, Great Britain (Stewart et al. 2004, 2007), is showing a long-term decline in migratory birds with wind development, providing a strong correlative relationship between wind development and long-term avian declines.<sup>1</sup>

Herder: Through NEPA we have an obligation to look at cumulative impacts, within and across district boundaries. The key piece of information that's missing is the size and extent of the range of the species being impacted. We don't have that information for a lot of species, which makes it hard to measure cumulative impacts.

Thompson: Two things exacerbate the challenge of measuring cumulative impacts.

1. We are seeing declines in a lot of bird species before the development of the wind industry, particularly for migratory birds; and
2. Mapping the size and range of bird species entails an international view as well as a cross-agency approach (for example, the loss of CRP lands, production of corn ethanol – USDA has to get involved).

***Genevieve Thompson mentioned the need to address habitat fragmentation; what is industry doing now, and from the agencies' perspective, what could they do?***

Anderson: As an industry, we're constantly faced with question of what to do from both an individual project and a habitat impacts perspective. This was a tough issue for the FAC to grapple with. How do we look at impacts from a landscape perspective, not just the project? The FAC's recommended tiered process addresses the issue, but absent a data repository that would allow us to start mapping those

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<sup>1</sup> Stewart, G.B., A.S. Pullin, and C.F. Coles. 2007. Poor evidence-base for assessment of wind farm impacts on birds. *Environmental Conservation* 34:1-11

landscape effects, it's hard to know. That said, I don't know what other industries are even thinking about these issues; certainly not building developers.

Herder: It needs to start at the project level. But it continues to be an onerous task to scale up from the project to a landscape level. I think we're doing a good job of looking at habitat fragmentation impacts at the project level. Mining and other types of renewable energy are looking at this. BLM and other agencies are looking at habitat fragmentation and so are the state wildlife agencies, which has been part of their work all along.

Librandi Mumma: At PGC, we had to pick and choose what all data we are asking developers for. It is challenging to look at habitat fragmentation amidst all the other issues we're charged with looking at. Habitat fragmentation is being looked at by other state agencies and some non-governmental organizations.

Manville: The Wind FAC did struggle with this issue. On the agenda for our Service Wind Turbine Guidelines Working Group meeting next week is how to take the recommendations from the FAC, including those related to habitat fragmentation, and work toward developing draft guidelines.

The Interior Secretary received the FAC's recommendations last spring, and the Service Working Group began a detailed review of the FAC recommendations this past summer. We are in the process of developing draft guidelines. Because there are policy issues and cost effects, the Office of Management and Budget has been advised regarding our developing draft guidelines. OMB may take up to 90 days to review and provide comments to FWS on our draft guidelines and *Federal Register* notice. FWS must then respond to any questions from OMB. Our draft guidelines will be open for 90 days of public review and comment via a notice of availability in the *Federal Register*. Comments from the public must then be incorporated into our final guidelines. This timeline puts us well into 2011.

#### ***How do we know we're moving forward?***

Manville: These are not easy issues. We have to base our decisions on hard science. That said, I'll take the worst wind project over the best mountaintop mining project you could present to us.

Thompson: We will be doing better when our political leaders address climate change or renewable energy...

Librandi Mumma: We do need to educate the public about these issues and why they matter. For example, landowners don't understand why researchers need to be on their land doing research, counting dead birds.

# Session 2. Fatality Impacts to Birds and Bats

## Part 1: Estimating Impacts

Moderator: Keith Hastie, U.S. Fish & Wildlife Service

### *Updated Summary of Bird and Bat Fatalities from Wind-Energy Facilities\**

[Kimberly Bay](#), WEST, Inc.

(co-authors: Wally Erickson and Matt Kesterkerke, WEST, Inc.)

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**Research objectives:** Provide an updated summary of the number of fatalities of birds and bats at wind-energy facilities from publicly available reports. Provide a cumulative review of the available data, the compilation of which has allowed for regional and temporal comparisons for both birds and bats. Hopefully shed more light on peak fatality periods and regional differences. Summarize species composition, distance from turbine patterns and general habitat patterns. All of the above summaries are completed for birds, bats, and bird types (i.e. raptors, passerines, etc.). A comparison of this size has not been available to date.

**Key words:** mortality, raptor, post-construction, fatality estimate, bias trials

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#### **Background**

Upon the completion of the construction of most wind-energy facilities, formal bird and bat monitoring (fatality surveys) is conducted by trained consultants and will occur at most sites starting the first year of commercial operations. Typically at least 1 year of post-construction mortality monitoring will occur—more where specified by permit or voluntary agreement, where the first year’s monitoring suggests an extraordinary fatality rate or where weather conditions are highly variable, substantially affecting migration timing and intensity.

WEST has compiled data from 40+ publicly available post-construction mortality monitoring reports from wind-energy facilities across the county and spanning the timeframe of 1996 through early 2009. The data includes general study information, including: county, state, dominant habitat, survey frequency, dates, number of turbines at site and number of turbines searched, and other similar attributes. When possible, we have also compiled actual fatality-specific information, including: species, date the fatality was found, turbine/location of the fatality, and as much conditional information that was provided. Specific data were collected on approximately 8,000 fatalities, not all necessarily related to the wind-energy facility.

#### **Post-construction Fatality Study Methods**

Collision mortality has been the main focus for a number of bird types and species, including raptors, resident and nocturnal migrating songbirds, waterfowl and other water birds, and threatened and

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\* Slide presentation not available as part of this Proceedings.

endangered species. Field methods for studying collision impacts typically include scheduled carcass searches around a random sample of project turbines, and searcher efficiency and scavenger removal trials used to estimate the rate of carcass removal and the proportion of remaining carcasses found by searchers. Resulting bias rates are used to adjust fatality estimates to come up with the number of fatalities/MW/study period.

Most studies assume that all fatalities found are caused by wind turbines, although the proximate cause of death often cannot be determined based on the condition of the carcass. A Minnesota post-construction study found that background fatalities accounted for 33% of fatalities, suggesting that mortality attributed to wind turbines may be inflated.

**Where the Data Come From**

It can be difficult to get an “apples to apples” comparison of fatality rates from different wind energy facilities. Studies are conducted at projects of varying size, habitat types, and turbine characteristics. Study period lengths, search intensity, plot sizes, and search methods vary. Bias trial methods and estimates vary, etc.

Data included in this study come from a total of 61 phases/years of studies conducted between 1996 and 2009 at 43 wind-energy facilities across North America (40 in the continental U.S., three in Canada). All estimates have been adjusted using bias trials, and all of the data is publicly available. Some notable studies have not been included due to a lack of standardization, older study methods, or older generation wind-energy facilities. Most of the studies included in this summary were conducted in eastern, western, and upper-mid-western U.S. Studies are being done in the central part of the country, but the data is not all publicly available.

**Summary Findings – Raptor Mortality**

Raptor mortality results were summarized from studies with bias trials conducted at 26 wind energy facilities over 38 phases/years, broken out by region. Raptor fatalities/MW/study period range from 0.03 to .87, with nine facilities reporting no raptor fatalities.

Buteos and Falcons account in roughly equal proportions for 92% of 204 recorded diurnal raptor fatalities. Species of the genus *Accipiter*, eagles, kites, and Northern Harrier make up the rest. Sixty vulture and 41 owl fatalities were also found in these studies, not all of which conducted bias trials. Breaking out diurnal raptor fatalities by species, kestrels and hawks (Red-tailed and Swainson’s) make up the bulk of the fatalities:

Raptor Species	Fatalities	% Comp
American Kestrel	89	43.63
Red-tailed Hawk	72	35.29
Swainson's Hawk	12	5.88

**Pre- and post-construction data comparisons.** Raptor use (#/plot/20-minute survey) was plotted against mortality rates (#/MW/study period), using data from 18 publicly-available pre- and post-construction studies. Data are clustered at the low-use, low-mortality corner of the plot, with two sites showing high-use/higher-mortality (0.4-0.9/MW/study period) results. Absent data in the middle, it is best to assume a simple use-fatality relationship. Note that these are data from short-term (one-year pre-/post-

construction) studies, and that 14 of the 18 studies were conducted in Oregon and Washington. More data are needed.

### ***Summary Findings - All Bird Mortality***

Across all of the public studies reviewed, a total of 2,431 avian casualties were recorded, 95% of which encompassed 202 identifiable species. (The remaining 121 fatalities were unidentified birds.)

Mortality results were summarized for all birds from studies with bias trials conducted at 43 wind energy facilities over 61 phases/years, broken out by region. Most of the results range from 0.08 to just over 7 fatalities/MW/study period, with one outlier – an eastern facility reporting 13.93 bird fatalities/MW/study period.

Summarizing bird mortality by avian type, we found that passerines make up the bulk of fatalities (1,570, or 64.58% of overall avian fatalities). Raptors and upland game birds are the next largest groups (8.39% and 6.83% respectively). Passerine fatalities were found at 66 wind energy facilities. The most commonly found bird species are horned larks (344, or 14.15% of fatalities) and golden-crowned kinglets (136, or 5.59% of fatalities).

Conclusions about the timing of bird mortality for those studies which include fatality date information are limited by search effort; many studies focus primarily on spring and fall seasons. For larger birds, mortality data show a slight peak during August-October. For small birds, the data show a more marked peak in May and again in September and October.

### ***Summary Findings - Bat Mortality***

Bat mortalities are also summarized by region for a total of 61 phases/years at 43 wind energy facilities (all with bias trials). The study periods among bat studies are very different. Markedly higher fatality rates are seen in the eastern United States and in the upper Midwest.

A raw count of bat fatalities by species at a total of 66 facilities (not all of which conducted bias trials) shows hoary bats leading the list with 1,774 (or 39%) of the 4,549 total fatalities recorded. Eastern red bats (17.8%) and silver-haired bats (14.9%) make up the second and third most commonly recorded fatalities.

Most of the bat mortality studies were completed in the fall. Again, the date of fatalities is not recorded for all fatalities, limiting summary results about the timing of bat mortality. A summary of existing study data shows a marked peak in mortality during the month of August, followed by September.

A turbine lighting and mortality study that looked at night-migrant mortality rates and at the relationship of fatalities to aviation obstruction (FAA) lighting at 30 wind energy facilities across North America (Kerlinger et. al 2010 *in press*). Non-parametric analysis revealed no statistically significant differences between fatality rates at turbines with FAA-approved lights compared to turbines without lighting.

### ***Conclusions and future directions***

The conclusions we can draw regarding bird fatalities are consistent with earlier reports, even as the amount of data has nearly doubled. More variability exists among the bat fatality estimates, with a

larger difference between regions. Higher bird fatality rates are seen in the spring and fall; much higher bat fatality rates are seen in the fall. For birds, the mortality patterns we are seeing are consistent.

Our ability to make better risk assessments is increased with the availability of data and the analysis of meta/cumulative data across the United States.

## Questions & Answers

***Please describe what some of the background fatalities were that could account for 33% of fatalities at one of the generation sites from which you obtained data.***

Bay: There was a Minnesota study that looked at a plot not associated with a wind turbine. Fatality estimated there was 1/3 of what was estimated at wind turbine plot, so that is the basis of 33% background mortality.

***Your study involved 43 wind facilities; what was the average number of turbines at each location?***

Bay: The number of turbines was highly variable from one site to another – one facility had 3 turbines, the largest had 54, with a lot in the middle of that range.

***Do you study difference in avian use pre- and post-construction?***

Bay: Not in particular.

***It looked like a few projects had very high fatality. Is there anything unique about those projects that we can learn from?***

Bay: There's nothing really other than regional variation.

***Why didn't you present adjusted estimates in your tables of % fatalities for bird or bat species?***

Bay: We are trying to move in that direction, but we do not yet have that capability.

***How many facilities did you get data from in California, and what is the most recent data included in your presentation?***

Bay: 6 CA sites but didn't include the older generation facilities. Most recent data are from 2009.

## ***Estimating Bird and Bat Mortality at a Wind Energy Facility in North-Central Texas***

[Amanda Hale](#), Texas Christian University

(co-author: Kristopher B. Karsten, Texas Christian University)

[Link to Presentation](#)

**Research objectives:** 1) Estimate bird and bat mortality at a wind energy facility in Texas - a region that has been under-studied with respect to wind-wildlife interactions; and 2) Test how precision (or lack thereof) of searcher and scavenger bias estimates can impact estimated mortality.

**Key terms:** bats, birds, fatality rates, scavenger removal trials, Texas

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### **Background**

Texas Christian University (TCU), located in Fort Worth, Texas, is partnering with Oxford University and NextEra Energy on a wind research initiative that looks at the wildlife (birds and bats), carbon, and socioeconomic impacts of wind development. Texas generates more wind energy than any other state, but we have very little data (to date) on fatalities.

Obtaining accurate and reliable estimates of mortality is necessary to compare mortality across sites, understand impacts on populations, explore relationships between pre-construction activity and post-construction mortality, and test the effectiveness of curtailment experiments, deterrents, or other mitigation practices. From 26 March to 30 October 2009 and 11 July to 15 October 2010, we conducted systematic fatality searches at a subset of the wind turbines at the Wolf Ridge Wind Energy Center in north-central Texas. We estimated bird mortality in 2009 and bat mortality in 2009 and 2010.

The Wolf Ridge Wind Energy Facility, owned and operated by NextEra Energy Resources, began operations in October 2008 and consists of 75 1.5-MW GE turbines extended over 48 km<sup>2</sup> within the cross timbers and prairies eco-region of Texas. The diverse landscape consists of shrub-woodlands and agricultural lands used primarily for cattle grazing, hay fields, and winter wheat. The project area is bordered to the south by open grassland and winter wheat, and to the north by forested area and the Red River.

### **Methodology**

We began monitoring in 2009 using a line transect method to search 32 turbines at 6-day intervals. After 13 weeks, we switched to using a rope method, conducting daily searches on 14 turbines for the remaining 17 weeks of the study period. (Because the study was not a condition for permitting the site, we had the flexibility with regard to the study design.) We continued using the rope search method with the same 14 turbines and 1-day search interval in 2010.

### **Observed fatalities**

Over the 2009 study period, we found a total of 100 bird carcasses representing more than 30 species, and 458 bat carcasses representing 5 species, mostly eastern red bats (*Lasiurus borealis*) and hoary bats (*Lasiurus cinereus*). Bird fatalities were equally likely to occur across the months of our study; the vast majority of bat fatalities occurred between mid-July and mid-September, coinciding with the fall migration season for North American tree bats. Slide #6 shows the number of carcasses/featherspots found across both years of monitoring. (The 2010 study period was ongoing at the time of presentation.) The pink arrow shows the 2009 start date; the yellow arrow shows the date (mid-July 2009) when the search methodology was changed.

Slide #7 shows bird fatalities by species group. Diurnal raptors (Black Vultures and Turkey Vultures) were the most common fatalities, followed by Yellow-billed Cuckoos – a puzzling find because cuckoos were generally not seen on the site. The overall level of fatalities was higher in 2009 than in 2010, with the

peak occurring in mid-September 2009. Slide #7 also shows how the distribution of species fatalities shifted from one year to the next.

Slide #8 shows the number of bat fatalities found over the two-year search period, as well as the distribution of fatalities by species for each year. Eastern red and hoary bats were the most commonly found bat fatalities. Slide #9 gives a daily fatality index (bat fatalities per turbine) from each study year. This was calculated based on the number of fresh carcasses that were found during standardized searches. The highest fatality index was 1.2 bats per turbine in early March 2009. The fatality index is highly episodic, varying from one night to the next, even within the migration period. The overall level of fatalities was lower in 2010, but the overall pattern of fatalities was similar.

### ***Mortality Estimators***

A conceptual equation for estimated fatality is the number of fatalities found divided by the product of searcher efficiency (proportion of carcasses detected) and scavenger removal (proportion of carcasses not removed). We used several mortality estimators, including the 'naïve' and 'modified' estimators per Manuela Huso's terminology.

Slides #11-12 show the estimated fatality rates (birds/MW/study period) for non-raptors and raptors. Non-raptor bird fatality at Wolf Ridge is almost four times higher than the national average (per Wallace Erickson). Raptor fatality is higher also (about 0.85/MW/year versus 0.13/MW/year), but if you remove diurnal raptors, it is probably comparable to the national average.

Bat fatality rates do not differ statistically from modified to naïve estimator, but there is a significantly lower fatality rate for 2010 compared to 2009.

We applied three different mortality estimators to our dataset, and obtained three different estimates. Regardless of method, however, our estimates of bird and bat mortality were toward the high end of values reported in other studies.

### ***Accuracy of Fatality Estimates***

We also tested how precision in searcher efficiency and scavenger removal rates can influence estimated mortality. Searcher efficiency varied due to carcass type and size. Scavenger removal rates varied by season and by carcass type; carcass substitutes (i.e., mice and commercially available game birds) were removed at significantly higher rates than were bats and birds killed on site.

In 2010, we put out mice and bat carcasses to compare scavenger removal rates. Carcasses were tracked for 30 days. On day 1, 87% of both types of carcasses were still there. By day 3, however, many more mice had been removed compared to bats. Because a three-day search interval is more common than a one-day interval in mortality studies, we also sub-sampled our data to generate an estimated fatality rate based on a three-day search interval. With a one-day interval, use of bats or mice in scavenger removal trials makes little difference in the fatality estimate. But with a three-day interval, the estimated bat fatality rate doubles when scavenger removal data are calculated based on the persistence of mouse carcasses. The use of carcass substitutes can lead to inaccurate fatality estimates.

## **Conclusions**

Our data indicate that investing in robust sample sizes for searcher and scavenger efficiency trials can significantly improve precision of mortality estimates. We also caution that using carcass substitutes may lead to upward biased estimates of mortality.

Research objectives – including the level of precision needed – need to be clearly defined. Multi-year studies are needed to account for seasonal variation as well as inter -annual variation. Experimental work is needed on efforts that could minimize impacts to birds and bats, including curtailment and deterrents.

## Questions & Discussion

### ***What is the rope method?***

**Hale:** Essentially, you take one rope and wrap it around the turbine like a belt. A second rope is then attached to the first, and it is extended to its full length (in our case – 60m) out from the turbine tower. The search begins with one person at the end of the rope (60 m from the tower) and a second person 53 m from the tower. The two searchers slowly walk forward while keeping the rope taught and scan the ground looking for carcasses. In this way the searchers follow a spiral path around the turbine, and can focus on searching, not on following a line. (Turbines must be situated in open spaces, with no trees or shrubs.) Changing from the line to the rope method increased our searcher efficiency from 11% to 37%.

### ***Did you look at wind speed differences per year? Could that explain the differences between the years? (Was 2010 a bigger wind year?)***

#### ***1. Do you have a hypothesis as to why fatality changed from 2009 to 2010? Weather related?***

We have not yet analyzed these data, but NextEra has made them available to us and we are planning on looking into this issue. The lower bat fatality in 2010 could be due to differences in weather patterns. There could also be fewer bats migrating through the area in 2010.

#### ***2. Is this location on an important migratory path?***

The wind farm is located within the Central Flyway, an important migratory pathway for birds. The bat fatality data indicate that tree bats are migrating through the area, but we don't know the extent to which this area is important for bat migration.

### ***Between 2009 and 2010 you changed search area and changed protocol from 2 ha plot to 60 m radius circular plot (1 ha). Do these changes account for at least some of the differences in bat fatality levels from 2009 to 2010?***

**Hale:** No, the bat fatality rates presented here are based only on data collected during the fall migratory season. We eliminated data from the first 13 weeks of 2009 so that our analysis was based on the same plot size and searcher efficiency for both years.

### ***Did you correlate daily fatality index with nightly wind speed? Are there any weather correlations with high fatality nights? Do you have a hypothesis for the high bat fatalities?***

**Hale:** We have all of the weather data from the nacelle of each turbine. High fatality nights appear to coincide with low wind nights, but it's a real challenge to know which variables and which summary

statistics capture what is important to the bats. For example, is average wind speed, minimum wind speed, proportion of night with wind speed under a particular threshold the best predictor of bat fatality?

***Please explain what naïve and modified estimation biases are?***

Hale: Both naïve and modified estimators (as well as other proposed estimators) correct for searcher and scavenger bias, but both underestimate fatality, especially the naïve estimator. The modified estimator includes an additional term relating to the persistence and detectability of carcasses over time (i.e. it allows for a searcher to find a carcass in subsequent searches after having missed it in previous searches).

***What were your searcher efficiency rates?***

Hale: Searcher efficiency varies by species and method. For bats, searcher efficiency was 11% with the line transect method, 37% with the rope. For birds – large birds – searcher efficiency was about 85-90%. Season also mattered.

***You looked at bias using carcass substitutes for bats. Did you also look at bias using carcass substitutes for birds? (For example, substituting quail for passerines?)***

Hale: We did not have a FWS permit to salvage bird carcasses in 2010. In 2009, however, we did look at this question and found that bird substitutes were removed at faster rates than carcasses of birds killed on site.

***Were there differences in the freshness of the mice and bat carcasses you used?***

Hale: For searcher efficiency and scavenger removal bias trials, all carcasses were frozen prior to use.

***Do you have activity data for bats both pre- and post-construction?***

Hale: We do not have pre-construction bat activity data. Acoustic detectors were deployed on the ground and at the nacelles of two turbines in 2010. These data have not yet been analyzed.

***Are you confident that you covered Mexican free-tail maternity season?***

Hale: Probably so in 2009. For 2009, we found only 1 Mexican free-tail out of 450 bat fatalities. Our 2010 monitoring season didn't start until July, but no fatalities have been found (to date).

***How far from the study area is the riparian area to north?***

Hale: The entire northern area of wind farm abuts the riparian area. Turbines all are 10-20 km from the Red River itself.

***Is there any spatial relation in fatality between turbines closer to river?***

Hale: We found no pattern—variability, but no pattern.

## ***Bat Mortality at a Wind Farm in Southeastern Wisconsin (with a Special Focus on Investigating the Cause of Death for Bats Killed by Wind Turbines) \****

[Steve Grodsky](#), University of Wisconsin - Madison

(Co-authors: David Drake, Department of Forest and Wildlife Ecology; University of Wisconsin – Madison; Melissa Behr, Wisconsin Veterinary Diagnostic Lab; Andrew Gendle, University of Wisconsin – Madison School of Veterinary Medicine; Nicole Walrath, Wisconsin Veterinary Diagnostic Lab)

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**Research objectives:** Determining the proximate cause of death in bats killed by wind turbines.

**Hypotheses:** We hypothesized that bat fatalities at wind farms is more abstract than the distinct differentiation between barotrauma and direct collision alone.

**Key terms:** barotrauma, bat mortality, blunt force trauma, proximate cause of mortality, Wisconsin

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This project focused on evaluating potential impacts of a 129-MW wind energy facility in southeast Wisconsin on bird and bat mortality during a two-year study period from the summer and fall of 2008 to the spring of 2010. We aimed to further uncover the proximate causes of bat mortality at wind farms by veterinary analysis of dead bats using radiography, histology, and necropsies.

The objective of better understanding the proximate cause of death is to improve our ability to target mitigation management. In other words, the more we know about how the bats are dying, the more tools we can develop for our mitigation tool box.

### ***Hypotheses***

Baerwald, et al. described barotrauma in bats for the first time in 2008. In the vortex zone created by the turbine, bats' lungs can implode. Direct collision with turbines has also been verified by thermal infrared imagery (Horn, et al. 2008). We hypothesized that bat fatalities result from a combination of the collision and barotraumas events. Barotrauma causes immediate death, whereas direct collision may have sub-lethal effects.

### ***Methods***

Twenty-nine randomly selected turbines were searched for bat fatalities during fall and spring field seasons in the years 2008 and 2009. Dead bats found during the fall 2009 field season were radiographed, tissue-sampled, and necropsied at the Wisconsin Veterinary Diagnostic Lab to provide empirical data pertaining to cause of death.

Radiographs were randomized and evaluated by a board-certified radiologist who was unaware of the post-mortem necropsy findings. The location, number, and type of skeletal injuries were recorded. Hernias were identified, and the thoracic cavity was examined for pneumothorax, haemothorax, chest wall trauma, and pleural fluid accumulation.

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\* Slide presentation not available as part of this Proceedings.

“Operation Bat Drop” – We dropped 18 bats (obtained from the Wisconsin State Hygiene Lab after rabies testing) from the turbine nacelle (approximately 300 feet) to simulate what would happen to a bat in a barotrauma situation where free fall occurred without direct collision. The bats were radiographed before and after the drop.

We also looked at control sites, which had no bat fatalities, so that we could be fairly sure that all fatalities found on the site were caused by wind turbines.

### **Findings**

Bat species found during mortality searches included little brown bat (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), Eastern red bat (*Lasiurus borealis*), and hoary bat (*Lasiurus cinereus*). Of these species, the migratory tree bats (genera *Lasiurus* and *Lasionycteris*) comprised over half of the mortality for the fall and all of the mortality during the spring.

Radiology revealed that 71% of bat fatalities had at least one broken bone, whereas visual inspection alone indicated a far smaller percentage of bats with broken bones. Most had dorsal injuries, and 31% had hernias. The radiology evidence indicates that bats are being hit from above, not on the upswEEP.

“Operation Bat Drop”, simulating what would happen in a barotrauma situation without direct collision, showed that 20% of the 18 bats dropped had one new broken bone (lumbar vertebra, sacrum, ulna) resulting from a free-fall from 300 ft above ground level.

We necropsied a total of 33 bats, looking for air or blood in the thorax, and often found both. Obviously decomposed bats, as well as bats that had internally decomposed, were omitted from the necropsy study. Nearly a quarter (24%) of the bats had full stomachs, so evidently were feeding when the fatality occurred.

Samples of lung tissue and pectoral muscle tissue were examined to identify blunt-force trauma. Histology slides of inner ear tissue were used to try to identify barotrauma. Half of the samples showed hemorrhaging in the inner ear. Of the remaining samples, half showed no evidence of hemorrhaging, and the rest could not be determined.

In addition, 17 bats were sent to the Wadsworth Center of the New York State Department of Health (Albany, New York) for rabies testing. All 17 were rabies-negative, supporting existing evidence that a very high percentage of bats killed by wind turbines do not have rabies.

### **Conclusions**

Radiology appears to be the best way to determine proximate cause of death (one can tell more than just by necropsy). Doing the radiographs is not difficult, but a radiologist is required to read the radiograph.

Based on the extent of skeletal damage shown on radiographs and the necropsy results, many of the bats showed signs of death by direct collision with turbines, rather than or in addition to barotrauma. This conclusion is supported by the fact that haemothorax can be caused by direct collision as well as by barotraumAs.

Given the relatively high mortality rate of migratory tree bats, mitigation methods including temporarily shutting down night-time operation of wind farms during peak bat migration may be a viable management option. Additionally, proper placement of wind farms using pre-construction bat monitoring data and investigation into acoustic deterrents may help minimize bat mortality at wind farms.

## Questions & Discussion

***How far would the bird or bat be propelled after being struck by a blade? Do you have an estimated percentage of the bats not found by searchers?***

Grodsky: In terms of bats that were hit and killed, we were finding them mostly within 30 m of the turbine. The defined search area was 1.2 acres. Searcher efficiency for bats during the entire study was 38%.

***Did you find any evidence of bat fatality from exposure – that is, they survived a collision but were not able to fly away after being on the ground? Any estimate of the percentage of bats not found during fatality searches because of delayed mortality?***

Grodsky: We found three injured bats under wind turbines that appeared to have been struck by turbine blades. I can't quantify the number of bats that were injured and not accounted for during mortality searches. It is likely that sub-lethal effects are occurring; however, it is difficult to know how often and this study was not designed to examine sub-lethal effects. The development of such methodology would be very useful, but probably quite challenging to create.

***Is there any evidence that direct strike could (or did) lead to barotraumas simply from the blunt force impacts? If haemothorax can occur from blunt force trauma, does barotrauma ever exist as a cause of bat mortality? (Or could they all be cases of blunt force trauma?)***

Grodsky: We were convinced by a combination of diagnostics that haemothorax could result from blunt trauma. So such cases could be either.

***Bat Research News is reporting hernias in healthy bats. How probable do you think it is that hernia occurred prior to trauma?***

Grodsky: It is most likely that bats are getting the hernias from the trauma itself.

***You said that 24% of the bats had full stomachs. Did you see any difference among bat species in regards to foraging or stomach contents?***

Grodsky: There was no apparent relationship between bats with full stomachs and species composition. We found both migratory and resident bats with full stomachs.

***Can you explain your last slide about carcass distance from turbine relative to barotrauma, collision, or both?***

Grodsky: I'm trying to map out the carcasses with distance to turbine and associate fatality causes with distance. Cannot say proximate cause, but can say what injuries each carcass had sustained. Bats within 10 m of base of turbine had 0 broken bones, suggesting barotrauma. There are also some bats farther away that had no broken bones, but most were within 30 m.

## ***Relationships between Bat Fatality and Weather, Marine Radar, AnaBat, and Night Vision Data at a Wind Energy Facility in the Midwest***<sup>\*</sup>

[Greg Johnson](#), WEST, Inc.

(co-authors: Wallace Erickson, Donald Solick, Chris Nations, Jason Ritzert, Michelle Sonnenberg, and Kimberley Bay, WEST, Inc.)

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**Research objectives:** Quantify bat fatality, determine if there are any relationships between bat fatality and weather data, and to determine relationships between bat fatality and bat activity metrics determined through use of marine radar and bat acoustical studies for possible use in predicting or mitigating bat fatality.

**Hypotheses:** We hypothesized that there is no relationship between bat fatality and weather, or between bat fatality and concurrent data on bat activity as determined through use of marine radar and bat acoustical studies.

**Key terms:** acoustic monitoring, bat fatality, marine radar, weather, wind turbines, Illinois

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### ***Project description***

From August 1 to October 15, 2009, we conducted a study at a wind energy facility sited in a corn and soybean agro-ecosystem in central Illinois. We randomly selected 39 of the facility's 1.65-MW wind turbines for sampling. The turbines were randomly selected from those where landowner permission was obtained to clear crops around the base of the turbine.

Our objective was to quantify bat fatality, determine relationships between bat fatality and weather, and determine relationships between bat fatality and bat activity metrics generated by marine radar and AnaBat studies for possible use in predicting or mitigating bat fatality.

### ***Methodology***

***Fatality searches.*** Thirty-nine turbines were selected for sampling. When searching agricultural land, it is necessary to clear vegetation around the base of the turbine in order to conduct searches, especially when crops are at maturity. An 80 X 80 m square plot around each turbine was cleared prior to the study – a distance based on previous studies at the facility, where 83% of all bat carcasses were found within 40 m of a turbine. (From the turbine to the corners of each plot layout is a distance of 57 m.) The average cost is \$1600/plot for cropland landowner recompense – up to \$6000/ plot for a 160X160 m plot – in addition to the cost of mowing.

Searches were conducted from August 2 through October 15, 2009, which covered the period when 90.8% of the bat fatalities documented during previous studies at the facility occurred. Half the turbines were searched daily and half were searched weekly for bat fatalities. Scavenger removal and searcher efficiency studies were conducted to measure biases.

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\* Slide presentation not available as part of this Proceedings.

Nocturnal radar studies. The objective of the nocturnal radar study was to characterize bird and bat migration over the site and to determine if target passage rates were correlated with concurrent bat fatality rates. Marine radar<sup>2</sup> stations were established at two turbine locations. Four turbines that were being searched daily for bat fatalities were located within the 1.5-km radius radar detection range of one radar station, and five daily-searched turbines were located within the 1.5-km radius detection range of the other station. Data collected included flight direction, passage rates, and flight altitude of nocturnal migrants. During the study period, there were 48 occasions during which radar surveys were conducted at night and fatality searches were conducted the following day.

Night vision surveys. Night vision surveys were also conducted in conjunction with the radar and AnaBat studies. The primary objective was to determine proportions of radar targets comprised of birds and bats flying at low altitudes – i.e. at or below the height of the turbine blades. A secondary goal was to observe interactions of bats and birds with the turbines, and to record bat and insect activity in proximity to the turbines.

Acoustic detectors. AnaBat™ SD1 detectors were placed near the ground at six fixed stations. At two of these stations, ground detectors were paired with detectors raised on the turbine nacelle. The paired stations were placed at turbines where the nocturnal radar and night-vision surveys were also being conducted. An additional two (roaming) detectors were moved among eleven locations to increase spatial coverage. The objectives were to: 1) estimate the level of bat activity at the facility; and, 2) determine if activity levels at ground or turbine hub height are correlated with fatality levels.

### **Findings**

The estimated bat fatality rate was moderate compared to other facilities in the Midwest, with migratory tree bats (hoary, eastern red, and silver-haired bats) comprising 98.7% of casualties. Most (71.7%) were found intact, 24.6% were scavenged, and 3.7% were found alive but injured. The vast majority of fatalities (97.7%) were found 40 m or less from a turbine. The highest bat mortality occurred during the one-month period from August 16–September 15, when 61.4% of all fatalities were found.

Bat fatality rates were relatively well-correlated ( $R^2 = 0.63$ ) with bat activity levels at raised AnaBat units, but not with ground stations ( $R^2 = 0.24$ ). About half of the turbines were lit with FAA lighting, but we did not find any significant difference in terms of bat fatalities with or without lighting. (This is consistent with other studies.)

There was a weak positive relationship between bat fatality and horizontal mode passage rates from marine radar data. Adjusted mean horizontal passage rates averaged 154 targets/km/hour, which is moderate compared to what has been measured in the eastern U.S. There was a weak negative relationship between bat fatality and target airspeed, which averaged 8.85 m/s overall. No relationship was discerned between fatality and vertical passage rate (mean =  $257.2 \pm 7.4$  targets/km/hr).

The mean flight altitude was  $359.0 \pm 1.5$  m (mean  $\pm$  SE) ( $n = 26,791$  targets) above radar level. Approximately 12.3% of targets had flight altitudes less than 125 m (the zone of risk posed by turbines). Among 100-m height classes, the highest percentage of targets occurred between 200 and 300 m above radar level. Targets were generally flying toward the south, with most targets recorded between 5 and 10 hours after sunset.

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<sup>2</sup> Furuno FR1510-MKIII X-band radar, transmitting at 9,410 MHz with peak power output of 12 kW.

Of the 224 targets observed during the night vision surveys, 51.3% were bats, 27.8% were birds, and 20.9% were unidentified. Most targets (88.0%) did not show any obvious reaction to wind turbines. Slightly more birds than bats altered their course in the vicinity of turbines (9.0% of birds and 6.0% of bats). All of the individuals that inspected turbines (2.1%) and both of the two observed collisions (0.8%) were bats. (Neither of these fatalities experienced barotraumas.) However, because 82.0% of bats did not show any reaction to turbines, these data imply that turbines are not a strong attractant to bats at the scale examined.

AnaBat stations at ground level recorded a mean pass rate of 11.65 passes per detector-night, while stations placed on turbine nacelles detected 3.58 bat passes per detector-night. Hoary bats comprised 9.9% and eastern red bats comprised 12.0% of total passes detected within the study area. Our results suggest that bat activity levels from raised AnaBat units were more correlated with bat fatality than marine radar data, and that bat fatality rates for all species were relatively well-correlated (adjusted  $R^2 = 0.63$ ) with the total number of bat passes per detector night at raised stations, whereas the adjusted  $R^2$  for bat fatality rates of all species and bat activity levels at ground stations was low (0.24). For hoary bats, the adjusted  $R^2$  for fatalities and number of AnaBat detections was 0.51 for raised units and 0.04 for ground units; implying that activity on raised units is a much better predictor of hoary bat fatalities, although it is not an extremely strong relationship.

The activity level of eastern red bats at ground AnaBat stations was very poorly correlated with eastern red bat fatality (adjusted  $R^2 = 0.03$ ), while eastern red bat activity at raised units was more strongly correlated (adjusted  $R^2 = 0.36$ ). The best predictor of eastern red bat fatality, however, was activity levels of all bats combined at raised AnaBat units ( $R^2 = 0.49$ ).

Bat fatality rates increased with nightly temperatures up to 72 deg F. Mortality was higher at lower wind speeds, but neither of these correlations was very strong.

### **Conclusions**

These study results provide data useful for designing pre-construction bat risk assessment studies and developing measures to mitigate bat fatality at wind projects.

- The data suggest that acoustic monitoring at raised stations may be a better indicator of bat fatality for pre-construction assessments of bat fatality risks than bat activity levels measured on the ground.
- Bat fatality increased with higher passage rates detected with radar.
- Bat fatality levels were higher on nights with greater proportions of low wind speeds.
- Bat fatality levels increased when flight speeds were lower as determined from radar.
- Night vision studies indicated that bats were not strongly attracted to turbines at the scale examined.

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## Questions & Discussion

### ***Do we know anything about efficiency of bat sonar?***

Johnson: It is not known to what extent bats echolocate while migrating, and even if they are echolocating, they cannot echolocate at the distances required to detect turbines in time to avoid them.

***How is the AnaBat device mounted on the nacelle?***

Johnson: It was placed in a weatherproof container and the container was fastened to the cooling unit using ratchet straps.

***Did AnaBat detection decrease with increase in relative humidity?***

Johnson: We did not look at humidity.

***At what distances did bats “react” to turbines?***

Johnson: Very few did react; I am not sure what the distance was.

***Apart from the one landowner who refused to let you do study on his land, was it hard to convince landowners to get you do studies on sites? Did anyone have concerns about data being used against them?***

Johnson: It was hard to get permission from a few of the landowners. Developers might want to include a crop clearing provision in leases with landowners.

***Did crop-clearing itself alter the habitat in terms of bats or bugs?***

Johnson: We have some anecdotal information about insects being attracted to turbines, because they have to be cleaned off periodically. Presumably, the bats were just migrating, and were flying over the area without regard to habitat below. We do know that killdeer and horned larks were attracted to those cleared plots, and these two species comprised most of the avian fatalities.

***Do we have any data for any wind facility for passage rates both before and after construction? That is, does the presence of turbines ever modify passage rates?***

Johnson: We did not find any significant difference between pre- and post-construction that could be tied to turbines.

***Did the AnaBat or radar measure the proportion of bats traveling beneath the rotor swept area and within the rotor swept area? If so, what were the proportions?***

Johnson: Due to ground clutter and resolution of radar below 50 m we did not try to separate targets as flying below versus within the turbine rotor swept area.

***How close was project site to intact forest or woods?***

Johnson: There is one state park nearby, but 90% of the area is in crop land.

***Were any Myotis calls detected with the AnaBat detectors?***

Johnson: Twenty percent of the calls were high frequency (*Myotis* and *Pipistrelles*)

***How did you orient the antenna to obtain vertical passage rates?***

Johnson: We alternated between horizontal and vertical radar orientation to get equal parts horizontal and vertical passage rates over the course of the night.

***Was there strong correlation between passes recorded by the AnaBats and fatalities?***

Johnson: The best correlation was between passes recorded at the nacelles and fatalities.

## Part 2: Statistical Analysis of Impacts

**Moderator: Dale Strickland, WEST, Inc.**

Statistics can be used in estimating fatalities, also in other aspects of wind-wildlife interaction, including pre-construction prediction of fatalities and prediction of risk. Statistics are also used in the analysis to help us understand the mechanism of how fatalities occur. In this section presenters provide examples of more detailed statistical analysis of the impacts of wind on wildlife.

- Jeff Gruver will talk about using statistical analysis to discriminate among bat echolocation calls, an important step in estimation of occurrence and thus exposure to risk.
- Roel May presents a statistical model for estimating collision risk for White-tailed Eagles. Post-construction estimation of fatalities must take into consideration important biases.
- Regina Bispo describe the use of parametric survival models as substitute for empirical estimation of carcass removal rates, an important bias that must be considered in estimating fatalities.
- Several studies have estimated the importance of variables such as topography and turbine type; Manuela Huso offers suggestions for improving these studies.

### ***Using Discriminant Function Analysis and Other Quantitative Techniques to Classify Bat Echolocation Calls***

[Jeffery Gruver](#), WEST, Inc.

(co-authors: Shay Howlin, Chris Nations, and Trent McDonald, WEST, Inc.)

[Link to Presentation](#)

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**Research objectives:** Develop quantitative tools to achieve species discrimination for application and assessment of bat risks at proposed and existing wind projects.

**Key terms:** discriminant function analysis, echolocation, neural network, occupancy, species identification

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Studies of bats at proposed wind energy facilities have become standard operating procedure, which gives us a lot of data – albeit spread out over a number of different sites and studies. But having a lot of data creates certain workload limitations. Other talks at this meeting have mentioned the need for efficiency, accuracy, and standardization, and that is the focus of this work.

A general question of interest is “What is the relative level of risk to bats likely to be at this site?” We generally estimate an overall level of activity, the usual metric being the number of bat passes per unit effort (detector per night). We have refined that metric somewhat over the years, distinguishing between low and high-frequency species, which somewhat corresponds to species of management interest. But not being able to reliably and consistently identify bat echolocation calls to species may hamper efforts to understand the risks to various species associated with operation of wind energy facilities. Can we do better?

More specifically, can we identify bat species by their echolocation calls? The answer is not as obvious as it might seem, especially to bird biologists who identify species based on bird call data all the time. The question has been debated rigorously among the bat researchers. There are two basic approaches to identifying species by echolocation calls: qualitative and quantitative.

- Qualitative species identification by experts is opinion-based and unrepeatable; it can mask uncertainties in species identification.
- Quantitative species identification is model-based; repeatability is high, meaning that if I run a data set with a particular model, and someone else runs that data set with that model, we’re going to get the same results. This approach highlights the uncertainties in identification – that is, there will be false negatives and false positives, and we can quantify those.

I am going to talk about two quantitative models: 1) a discriminant function analysis (DFA); and, 2) neural network analysis.

### ***Discriminant Function Analysis***

Discriminant function analysis is a multivariate statistical function analytical method for group identification. It requires a training data set to build the model and identify call parameters such as duration, minimum/maximum frequency, certain slope characteristics, etc.

Software is available to go through your set of known variables and extract those parameters; when these are plotted in multivariate space, certain variables fall out as being useful for discriminating one group from another. For example, canonical variate 1 (i.e., heavy weighting on minimum frequency) – does a good job of separating certain groups, while another canonical variate does a better job of separating other groups. We are not very good at visualizing things in multidimensional space, but this DFA is able to take all 10-11 of those variables and plot them simultaneously.

You can then take your unknown – a bat call that you want to identify to species – and plot it in that same multivariate space to determine which groups it most likely belongs to.

We used a library of 640 known calls to build our DFA training data set. This was a set of good quality calls, long sequences – which is not typically what you would get with passively collected data. You may get bat passes with two or three good pulses, passes with five to seven pulses. We bootstrapped the number of pulses from our known data set to see how that affected classification success. What we found was that at about five pulses, classification success seemed to flatten out. So for our protocol we standardized to five pulses in a pass.

Slide #10 gives an example of output from the DFA model: the table shows true species versus how the model classified it. The model was better at classifying some species (big brown bats versus eastern

small-footed myotis, for which there was a relatively small sample size). Overall the model had a 90% correct classification rate.

We can get greater accuracy if we give up some precision by grouping species together. For example, by grouping big brown and silver-haired bats, which have similar echolocation calls, we improved to a 96% correct classification for that group. We were able to do the same for red bats and evening bats. We left out the gray bats and hoary bats (in part because we could classify hoary bats on their own with high accuracy). We grouped the other *Myotis* species together and left out the tricolored bats, and that group-wise discriminant function did very well. Grouping the silver-haired and hoary bats along with the reds, evening bats, *Myotis* and pipistrelles (i.e., tricolored bats) gave us a 99% correct classification rate. Thus for a much lower time and cost investment, we can get the same results as we could by having an individual look at each call and try to identify it based on qualitative expertise.

### **Neural network results**

With the help of statisticians, we developed a neural network, a similar classification model to the DFA, except that it is non-linear. Whereas a linear DF allows you to fit an n-dimensional hyper plane to species, with neural networks you are able in a sense to “curve around.” It is still not 100% correct; we have false negatives, false positives. But this multilayer classification yielded about a 93% correct classification. (I would stress that this is a preliminary look at the neural network model; our statisticians inform us that we can do better.)

We also looked at another approach, “K nearest neighbor.” This yielded about 85% correct classification across the board, so we are not planning to pursue that.

If we look at those species for which the classification rate was similar using all three models, the Indiana bat, which is of particular interest in the Midwest and the East, was about the same for all three models – about 90% correct classification. *Myotis sodalis* is a very difficult species to distinguish acoustically from two of its more common congeners.

### **Practical example of application**

We are still presenting data for a lot of our projects in the “classical” fashion – number of passes per detector-night. We can split those out into different species groups in certain situations. In this case, we used three detectors – one elevated on a met tower, another at the base, and a third at ground level away from the tower – to gather acoustic data from April to October at a proposed wind energy facility in the Northeast.

We initially analyzed and presented this data in the usual fashion: high, medium, and low relative activity levels. The distant ground-based detector had lower overall activity than met tower ground-based detector, and the elevated detector had the lowest of all – a very common pattern. Low-frequency species tend to be more common at the elevated stations.

Of the 15,000 or so bat passes, about 6,000 were passed through the DF model for analysis. We presented occupancy rates for seven species, where we defined “occupancy” as at least one night of detection for a species. We filtered the bat passes in Analook, using the filters to get rid of the noise – e.g., bat passes with fewer than five pulses. We saved the call parameters from an individual pass, averaged the pulses and only accepted the species classification if the posterior probability was greater than 95%.

At the ground-based station away from the met tower, the low-frequency species are not particularly abundant, whereas the high-frequency species are. At the met tower both the ground-based and the elevated detector picked up both high- and low-frequency species. Looking at the data by season, we can see that specific bat species were more common at different times of the year. The little brown bat was more commonly detected in the spring and a little less commonly in the fall; the pipistrelle was more common in the fall where as the big brown bat was more common in the summer.

Comparing this occupancy rate by species/group with the standard presentation (bat passes/detector-night), we can see that the met-based ground detector showed that the little brown bats and tricolored bat were more common than you might guess from the bat pass detector rate information.

## Questions & Discussion

***Can you say anything in regard to qualitative versus quantitative in terms of correct identification?***

Gruver: It depends on the expert. Some people can do better than others at identifying calls correctly. But once you develop a model, it is repeatable and consistent.

***How was the library of known bat calls that was used to create the discriminant function model developed?***

Gruver: Dr. Lynn Robbins and his students at Missouri State University collected the known calls during active acoustic sampling, and he shared it with us.

***You noted that your model was based on a call library of 640 calls. How confident are you that this is a statistically robust sample size, and does the library accommodate call variations across regions (i.e., dialects) or behavioral differences between lab and feeding in the wild?***

Gruver: I'd like the sample size to be larger, but I think it is a pretty good model for most species. In terms of regional variation, the larger source of variation isn't regional so much as the conditions in which the echolocation calls are recorded. E.g., there will be variation between hoary bats echolocating in a cluttered environment versus a clear area.

***What kind of detectors were used for data collection? Were time-amplitude data considered for analysis? What parameters were used to separate out EPFU from LANO?***

Gruver: We will use Sonabat software which is being developed to incorporate an automated call analysis function. However, this particular data set was AnaBat data.

***How accurate are bat acoustic detectors that are commercially available? Cost range?***

Gruver: The cost is \$950 to \$2500 for detectors. Full spectrum or time-expansion detectors would be expected to have better ability to identify species, but I am not sure that's been borne out yet.

***Is someone developing these data sets to use for different regions of the country?***

Gruver: Yes – Sonabat.

**Chris Corben developed filters using parametrics of calls for DFA, similar to your analysis. Are your parameters different from Chris'?**

Gruver: The parameters we used as inputs for the model are those Analook outputs. I believe those are the same parameters.

**What percentage of calls cannot be identified to species using the DFA?**

Gruver: When we ran the filters to get good quality calls, 38% were of sufficient quality that analysis in the DFA was considered to be appropriate. In practice, it may not get a lot better than 50% of all bat passes, though it's likely to vary among species.

**The last slide you skipped had a photo of McKinsey et al. 2006. Please explain how you plan to use occupancy modeling in your DFA. Will you extend the model to calculate potential abundance?**

Gruver: Using the DFA, we had a series of nights when we had detected species and not detected species, meaning we are able to construct a "capture history" for individual species. What we would like to do is use patch occupancy or similar models to develop more refined estimates of occupancy and to associate covariates with occupancy. We will likely not use this approach to estimate abundance.

## ***Spatio-temporal Assessment of White-tailed Eagle Collision Risk at the Smøla Onshore Wind Power Plant in Central Norway***

[Roel May](#), Norwegian Institute for Nature Research

(co-authors: Torgeir Nygård, Steinar Engen, Ole Reitan,  
Espen Lie Dahl, Kjetil Bevanger, Frank Hanssen)

[Link to Presentation](#)

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**Research objectives:** Construct a methodology to assess collision risk and avoidance in White-tailed Eagles with respect to wind turbines, based on the eagles' movement patterns.

**Key terms:** avoidance, Brownian bridge, collision risk, Norway, White-tailed Eagles

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Smøla is an archipelago in central Norway with one main island covering 274 km<sup>2</sup> and over 5,000 islets and skerries. The Smøla wind energy facility is the largest in Norway. It consists of 68 wind turbines and was built in two phases (2002 and 2005). Since 2005, 145 birds have been killed by collisions with turbines at the Smøla plant, including 42 Willow Grouse and 38 White-tailed Eagles (*Haliaeetus albicilla*). Other commonly killed species are the Common Snipe, Hooded Crow, gulls, Golden Plover, Graylag Goose and ducks.

In this study we constructed a statistical simulation model using Brownian bridge methodology for estimating collision risk rates. The study was one of a set of projects focusing on bird-wind turbine interactions, which is one of several focus areas for the Centre for Environmental Design of Renewable Energy (CEDREN) consortium. The aim of this study was to improve our understanding of where, when, and why White-tailed Eagles collide with wind turbines.

We began with a critique of the band-model, which is commonly used in Europe. The band-model consists of two stages:

- Stage 1 - Calculate the likelihood of a bird being hit by the rotor blades as it passes through the rotor-swept zone (RSZ), based on the technical specifications of the turbines and the morphology, wing aspect, average speed and flight behavior (flapping or soaring) of the bird.
- Stage 2 - Estimate the number of birds flying through the RSZ in a given time unit, based on field observations from different vantage points.

The band-model is straightforward, but stage 1 fails to incorporate stochasticity due to variation in wind speed or direction, rotor RPM, flight speed and directionality. Stage 2 is mainly based on field observations, so prone to bias and other error, which may not be dealt with in the analysis. These shortcomings are compounded when pre-construction predictions are compared with post-construction fatalities, and the difference is attributed to avoidance. (For example, if the prediction is 100 bird fatalities are predicted based on the band-model, but post-construction searches find only one bird, people may conclude that the avoidance rate is 99%.) We should be able to do better.

### ***A Brownian bridge approach***

This study aimed to improve on the band-model approach by making use of three-dimensional GPS telemetry data delivered at hourly intervals by 23 sub-adult eagles equipped with backpack transmitters (September 2005 – May 2010). Using the GPS data, we calculated the amount of time birds spent within the wind-power plant, and within the rotor-swept zones, over time. Using a *Brownian bridge* approach, we were able to make a spatial-temporal assessment of collision risks with turbines.

A Brownian bridge is a conditional random walk between successive pairs of locations, dependent on the time and the distance between locations and the Brownian motion variance that is related to the animal's mobility.

In this case, we know that the animal was at point A at time T-1, and at point B at time T, but we don't know what happened in between, so we calculate Brownian bridges in 1-minute intervals for XYZ coordinates independently, using at least one relocation within a 24-hour period and a minimum of 20 GPS positions per subset, to estimate expected position and variance. The "variance of Brownian motion" gives an idea of how mobile the animal is, captured in a diffusion coefficient. The calculation includes resting behavior as well as motion. We take both the mobility coefficient and the probability of activity into account, using regression to get a daily activity pattern.

We then estimated collision rates using Brownian bridges, taking account of telemetry error, and did this for each individual separately for each calendar year and month. This Brownian bridge simulation was iterated ten times to get a feel for the variation among simulations.

The z-coordinates were logit-transformed, bounded by 0 and 1000 m agl. The zero boundary determined bouts of activity; if the z-coordinate is equal to zero, the animal is on the ground, or resting. We then did the same interpolation for the x- and then the y-coordinates. Each simulation ended when the animal came to a rest. (If z-coordinate is not available, then activity bouts could be estimated based on the probability of activity.)

### ***Estimating risk***

Risk rates were defined as the proportion of flight time spent in the rotor-swept zone. We assessed risk first on the two-dimensional level, which defines the risk area as a circular buffer around the turbine tower within a radius equal to the length of the turbine blade (38.0 and 41.2 m, respectively, for construction phases 1 and 2). Risk can also be assessed in three dimensions, focusing on an altitude band in this case of 29-111 m. We also looked at how much time the animal spent in the wind energy facility area as a whole. Relative risk was defined as the 3-dimensional risk rate divided by the amount of time spent flying within the area encompassed by the wind energy facility.

### ***Results***

We used analysis of variance to assess the explanatory effects of gender, distance between nest and closest turbine, calendar year and month. We did not find any effect for distance of nest to nearest turbine. We do see that females spent more time within the wind energy facility, but in terms of relative risk, males spent more time when in the power facility actually flying in the rotor swept zone. First- and second-year old eagles spent more time in the two-dimensional risk zone.

Time of year (month) had the highest effect on risk rates of any factor we considered. In the first year, risk peaks in September (slide #22). This may have been the effect of animals actually born there within the wind energy facility. In the second and to a lesser extent the third year, we see a clear risk peak in the spring.

Comparing risk to the actual timing of collision fatalities (slides #23-24), we see fatalities peaking in the spring. A graph comparing modeled and recorded fatalities for sub-adults only shows a fairly close fit over the spring months, with the model over-estimating the likelihood of fatalities in the late summer and early fall.

Looking at sub-adults (1- to 6-year olds) and mature adults (7 years or older), fatalities were found to be clustered around the same turbines.

### ***Assessing avoidance behavior***

This model does not yet include effects of avoidance; however, it will be possible to plug in different types of behavioral responses in this model. Still, displacement and large-scale avoidance are included through the area use captured in the GPS data. Our results may provide industry and management authorities with new tools for assessing the extent of collision risks of wind energy structures.

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## Questions & Discussion

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### ***In Europe, is curtailment to mitigate mortality a more common practice? What is the Norwegian perspective?***

May: It has been discussed a lot in Norway as a possible measure. But unless you have a really good idea of when and where the problem occurs, you can't really implement curtailment.

***What was frequency of GPS position fixes (per day or per hour)?***

May: We used different tracking programs. The frequency was at best once per hour, but some transmitters were solar powered, so we didn't get any data in winter, got more in spring, a lot in summer, etc.

***Did the study look at how far adult eagles ranged from the nests during nesting season?***

May: Adult eagles range widely. The tracked sub-adults have shown to range along the entire Norwegian coast; going as far as up to the North Cape (over 2,000 km).

***What was approximate average time spent flying in the risk zone (in # minutes per day?)***

May: I don't have that number.

***What were the impacts, if any, of the wind energy facility on nest occupancy rates?***

May: It was thought originally that nest occupancy rates had gone down, but we have found an increase in nest occupancy just outside the park. So, the population has remained stable, but they seem to have moved their nests.

***How close to the turbines were the nests that were disturbed?***

May: Disturbed nests were 10-20 m away. There are others 100 m away from turbines that are still being used.

***Do mortality surveys suggest that immature eagles are more likely to be struck by turbines? And are there any plans to mark and track adult eagles in future?***

May: Collision fatalities are half sub-adults and half adults, so we would like to track adults as well. It's harder to capture adults, but then the sub-adults are going to become adults, so we will eventually be tracking both.

***Was there any belief that wind facility on Smøla would result in fatalities to White-tailed Eagles, and if so, why did they build it?***

May: It was controversial, but it was given the go-ahead, and especially after second phase was built, eagles started dying, and there was an official complaint given to the Bern Commission. This has resulted in official recommendations to avoid this kind of siting in the future.

## ***A New Statistical Method and a Web-Based Application for the Evaluation of the Scavenging Removal Correction Factor***

[Regina Bispo](#), ISPA-Instituto Universitário and CEAUL

(co-authors: Gustavo Palminha and Joana Bernardino, Bio3 – Estudos e Projectos em Biologia e Valorização de Recursos Naturais, Lda.; Tiago Marques, Centre for Research into Ecological and Environmental Modeling, St. Andrews, Scotland UK and CEAUL; Dinis Pestana, Departamento de Estatística e Investigação Operacional, FCUL and CEAUL)

[Link to Presentation](#)

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**Research objectives:** The research aims to solve the problem of estimating scavenging rates. We present a new statistical method and a web-based application for modeling data from removal trials and, ultimately, compute the scavenging removal correction factor.

**Key terms:** bias correction, carcass permanence, parametric survival model, R implementation, scavenging correction factor, statistical software

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### ***Introduction***

In monitoring studies at wind farms, the estimation of bird and bat mortality caused by collision must take into account carcass removal by scavengers. Current methods to accommodate mortality estimates for scavenger removal vary greatly. The lack of a reliable scavenging correction factor is mentioned in recent literature (*e.g.*, Kunz *et al* 2007, Arnett *et al* 2008) as an important source of unreliability in the estimation of bird and bat mortality.

Described methods for estimating mortality vary a lot. All are based on observed mortality ( $C$ ) adjusted by the probability of detection of the carcass ( $\pi$ ). The difference is in how we estimate that probability. Up to now, scavenging removal correction factors have been determined using either observed proportions or the mean time of removal over a period of time. In the first case, the correction is based on the grounds of empirical estimates, and in the second case, correction is based on the exponential distribution of “time until removal” (see Erickson 2000, Johnson *et al.* 2003, Erickson *et al.* 2004, Shoenfeld 2004, Kerns *et al.* 2005, Jain *et al.* 2007, Huso 2010).

Existing estimation methods have in common that they are based on scavenger removal trials where typically a certain number of carcasses is randomly placed underneath the wind turbines for an *a priori* fixed period of time. The underlying distribution of “time until removal” data collected from these trials typically is positively skewed and often includes right-censored observations because carcass monitoring, in most cases, is planned to end at a predetermined time. These types of data are not amenable to standard statistical procedures.

### ***Statistical analysis of carcass removal times***

To solve this problem we present a new methodology for the statistical analysis of the time of carcass removal using parametric survival models, assuming four main competing lifetime distributions (exponential, Weibull, log-logistic and log-normal). This methodology avoids reporting findings exclusively on the grounds of empirical estimates, using instead statistical models as a consequence of

proper comparative goodness of fit analysis regarding diverse plausible models. The method naturally accounts for the presence of censored observations and diminishes bias in scavenging rate estimation.

*The first step is to define the observed probability of persistence.* Assuming that carcass removals occur independently of one another, the Kaplan-Meier estimator gives the empirical probability of persisting until time  $t$ . This estimator accommodates the presence of censored observations.

*The second step is to choose the best distributional assumption to model removal times.* There are several probability distributions described in the literature as suitable for survival data.

- Exponential distribution is the simplest, and the one currently being used in the various estimators. It assumes a constant risk of removal. Is this plausible?
- Weibull distribution assumes a decreasing risk of removal over time for a shape parameter under one, which seems plausible.
- Log-logistic and log-normal distributions assume that removal risk could first increase and then decrease over time.

The final model is defined using stepwise procedures and excluding non-significant covariates. The model fit is analyzed using both the adequacy measures (AIC) and the graphical analysis. The probabilities of carcass persistence are estimated from the best-fitted model.

Slide #12 describes a scavenging correction factor based on the best-fitted parametric survival model. This estimator assumes that collision fatalities occur with the same probability at any time in the interval between consecutive searches. It is applicable to any search interval used in fatality monitoring protocols at wind energy facilities.

### ***Examples of applications***

We present one application example using data from trials conducted at a Portuguese wind farm. In particular, we show the results from one wind farm regarding the model accounting for season (with two categories) and for carcass size (with three categories) effects.

### ***Software implementation***

To help final users in applying the new methodology, we have created a web-based application that provides an easy-to-use interface for the implementation of the statistical procedure in *R Environment for Statistical Computing*. The application accommodates experimental designs that study up to four factors, with a maximum of four levels each. A template file is provided to organize the uploading of data. The software informs the user about the best model and presents both an empirical (Kaplan-Meier) and best-fitted model using tabular and graphical displays. Based on the best-fitted model, the scavenging removal correction factor is calculated, within the factor levels, for any time interval (time between searches) requested by the user.

### ***Conclusion***

To summarize, the proposed method:

- Avoids reporting findings exclusively on the grounds of empirical estimates;
- Accounts for the presence of censored observations;
- Diminishes bias estimation of the probability of persistence as estimation is based on the most suitable probability distribution;
- Allows integration of the estimation problem with the analysis of covariate effects; and

- Avoids performing several univariate analysis to test differences between covariates levels and hence enables to control the overall probability of making an incorrect decision regarding covariates effects.

This web-based application is publicly available.

## Questions & Discussion

***There is an underlying assumption here that each carcass removal is independent of others, but scavenger behavior indicates that a single scavenger attracts other scavengers. Could your methods be adapted to take that into account?***

Bispo: Modeling is a simplification. In this first phase we are working with the simplest situation, but we could go on to incorporate that factor.

***What did you use as scavenger bait?***

Bispo: We used three different sizes – Red Partridges, quails, and small passerines; we also used mice as surrogates for bats.

## ***Modeling the Relationship of Wildlife Fatality to Daily Weather or Activity Patterns: Statistical Design and Implementation Issues***

[Manuela Huso](#), Oregon State University

[Link to Presentation](#)

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**Research objectives:** Convey importance of informed statistical analysis

**Key terms:** collaboration, conceptual model, curtailment, interpretation, inference

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I am not going to talk about statistics today, but about collaboration and the need for statisticians and biologists to work closely together in coming up with study designs and statistical models, as well as in interpreting study results. We need strong conceptual models, jointly developed, to guide our work; we need to be very clear about what are we measuring, why, where and how.

Today I will talk about 3 related models of interest and some design issues that arise. We develop models that relate activity to fatality, primarily because we can measure activity pre-construction. We measure post-construction activity to look at the effectiveness of deterrence. We measure weather and correlate that with fatality data. We measure both activity and weather because we have an idea they may jointly impact fatality.

Our conceptual model is based on risk –

- More activity means more chance of accident, but what kind of activity, where and when and how do we measure it?

- Consider the chicken crossing the road. When we measure activity, are we measuring four chickens each crossing the road once, or one chicken crossing the road four times? It matters, because the way we map the correlation (linear or non-linear) is going to differ.

If our measure of activity reflects a single bat passing the turbine several times, then there is an asymptote on our fatality axis that won't be passed and may require non-linear response function. If our measure of activity reflects many bats each passing a single time, then perhaps a linear response function is appropriate. Our conceptual model will guide us in determining the appropriate statistical model.

Where should we measure activity? In practice, we measure activity below the rotor swept zone (RSZ), even though this is not consistent with our conceptual model. We could change our conceptual model: i.e. fatality is correlated with a surrogate of activity in the rotor-swept zone rather than actual activity. Or we could change our measurement to actually measure activity in the area where the fatality will occur (see Greg Johnson's earlier presentation). If we decide that our conceptual model is one that relates fatality to a surrogate of activity, i.e. activity below the RSZ, then we need to be very careful in interpreting results. If we find a strong relationship of fatality to activity measured below the RSZ, then there is no problem. However, if we do not find a strong relationship, that does not necessarily mean there's no relationship; it may just mean that activity measured below the RSZ is not a good surrogate for activity within the RSZ.

Based on our understanding of bat activity and wind speed and fatality, it looks like the relationship between fatality and wind speed is non-linear. This has implications for curtailment. From both an industry and a wildlife perspective, we would like to know how different cut-in speeds impact fatalities. In this experiment, we wanted to compare cut-in speeds of 5 m/s, 6.5 m/s, with the default cut-in speed of 4 m/s. Unfortunately, we cannot control the wind. When wind is low (below curtailment speeds) or high (above curtailment speeds) we can't distinguish among the three treatments. When we did this experiment, about 20% of the time, the wind was either too slow or too fast, so there was no distinction in turbine operation between the treatments and fully-functional. During 40-50% of the time, the wind was such that the fully operational turbines were rotating but all treated turbines were curtailed, so there was no distinction between the two curtailment levels. Only during about 10-15% of the time were the two treatments operationally distinct.

This study illustrates just one of many opportunities for thinking of conceptual models of how the world works and how we fit that into study design, measurement, and statistical modeling. If we can conceptualize our models well, the rest will follow. Researchers and statisticians should work closely at the outset of any study to develop meaningful conceptual models that can then be translated into useful statistical models.

## Questions & Discussion

***For the Casselman project, if this were to be conducted in a different place, do you have suggestions on how to tweak it to be able to tell the difference in treatments to a higher degree than occurred here?***

Huso: If I could control the wind, I would. But the only way to learn more is to increase the study period – even multi-year – to increase the amount of time when you can distinguish among treatments.

***Would differences among treatments become more visible over time?***

Huso: Hopefully, yes.

***How low can searcher efficiency rates be and yet still have valid fatality estimates?***

Huso: Low efficiency yields imprecise estimates. For example, compare the precision of fatality estimates when SE is estimated to be between 0.85 and 0.95 vs. when it is estimated to be between 0.05 and 0.15. Same spread, same distance from each extreme (0 or 1). Let's say 100 animals are killed, so we will find, on average 90 in the first case and 10 in the second. Our estimate of fatality in the first case will extend from 94.7 to 105.9 (90/0.95, 90/0.85) whereas in the second case it will extend from 66.7 to 200 (10/0.15, 10/0.05). Both estimates encompass the true fatality rate of 100, but the one from a study with SE=0.9 will be much more precise than the one from the study with SE=0.1.

***Are you working towards including wind speed as a covariate to address the limitations on treatment detectability?***

Huso: We are trying to develop models that incorporate wind speed/ blade movement as mentioned, but there is no easy way to summarize wind speed for the whole night to correlate with a specific fatality.

***How far are we from being able to predict bat fatality rates from pre-construction studies of bat activity?***

Huso: In the work that I've done, we're not close – but it may be that someone else is closer. This would be best addressed by a multi-site, multi-year study making good use of some of the existing data and data currently being collected at sites where both pre-construction activity and post-construction monitoring has occurred.

## Session 3. Impacts to Wildlife Habitat and Behavior

**Moderator: Bronwyn Hogan, California Department of Fish & Game**

Speakers in this session present preliminary and final research on a variety of questions having to do with habitat and behavior impacts to wildlife from wind energy development. We've asked presenters to help us think about the implications of their research for setting research priorities and the efficacy of current methods for predicting and estimating impacts.

### ***Greater Sage-grouse Habitat Use and Population Demographics at the Simpson Ridge Wind Resource Area, Carbon County, Wyoming***

[Greg Johnson](#), WEST, Inc.

(co-authors: Chad LeBeau, WEST, Inc.; Matt Halloran, Wyoming Wildlife Consultants)

[Link to Presentation](#)

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**Research objectives:** Measure seasonal habitat use and demographic parameters (survival, nest success, brood success) of a Sage-grouse population within an area containing one existing and two proposed wind energy facilities. Produce results that will: a) help the wind industry to make informed siting decisions; b) enable state wildlife agencies as they review proposals for wind energy developments in occupied sage-grouse habitats to provide input on methods to avoid and minimize impacts as well as measures to mitigate impacts.

**Hypothesis:** Wind energy development does not affect Sage-grouse habitat use or demographic parameters.

**Key terms:** demographics, displacement, Greater Sage-grouse, habitat selection, Wyoming

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#### ***Background and Study Objectives***

Numerous data collected on the response of Prairie Grouse to other types of developments (roads, oil and gas development, power lines, for example) have generated debate about the potential impacts of wind energy facilities on Greater Sage-grouse. We are currently conducting the first large-scale study to assess response of greater sage-grouse to wind energy development using lek survey and telemetry techniques to document seasonal (breeding, nesting, brood-rearing, winter) habitat use.

The study is being conducted in Carbon County, Wyoming, in a semi-arid cold desert area with one existing wind energy facility (Seven-Mile Hill) and two proposed facilities (Simpson Ridge and Pine Draw). The existing wind energy project consists of 79 GE 1.5MW turbines, constructed in 2008. The presence of the existing wind energy facility in the project area has allowed us to obtain some information on sage-grouse response to wind turbines the first study year.

The Simpson Ridge project area lies within a Sage-Grouse “core population area”, as defined by the Governor of Wyoming. (Note that the core population area as originally defined included Seven-Mile Hill and Pine Draw; the Governor’s Office re-mapped the core area so that it includes the same number of Sage-Grouse but eliminates some conflict with wind resource areas). The landscape is characterized by typical sagebrush habitat.

The objectives of this study were to:

- Determine locations of seasonally-selected habitats (e.g., nesting, brood-rearing, wintering areas) within the influence of the wind energy development project.
- Gather baseline data on demographic parameters (e.g., survival, nest success, brood success) so as to determine the impact of the wind energy project on Greater Sage-grouse within the project’s influence area.

### ***Study Methods***

A total of 12 leks were located within the Simpson Ridge Wind Resource Area (WRA) in Carbon County, Wyoming. These leks were surveyed to monitor long-term population trends, using the search and survey method outlined by the Wyoming Game and Fish Department. At the agency’s request, the survey area includes both existing and proposed wind projects and a four-mile buffer. Three fixed-wing aerial surveys were conducted to locate leks; we then conducted three ground visits to each of the leks.

Radio telemetry was also used to track female grouse, document nest locations and collect data on nest success, brood-rearing habitat, and fledging success. Female grouse were captured by spotlighting and use of hoop nets on roosts surrounding leks in April of 2009 (75 birds) and 2010 (41 birds). About two-thirds of the females were adults and one-third was yearlings. All were captured near seven of the 12 leks. A little over half (66) of the females were captured near or within the Simpson Ridge WRA; the other 50 were captured near Pine Draw WRA and the existing Seven Mile Hill wind energy facility.

Females were radio-collared with necklace transmitters equipped with mortality sensors so that we could locate dead birds quickly and try to determine cause of death. The transmitters, weighing 22 g and with a 666-day battery life, were manufactured by Advanced Telemetry Systems. Birds were tracked mostly from the ground using hand-held receivers, but aerial surveys were also conducted to locate missing birds and to locate birds during the winter when much of the area was inaccessible. Each radio-collared grouse was relocated at least twice per week during the pre-laying and nesting period, once a week during brood rearing to determine early brood-rearing habitat, and approximately every two weeks during fall, and once a month during the winter.

Nest locations were documented using homing techniques, and mapped using a GPS. For each nest, data were collected on timing of incubation and nest success, with clutch size determined by counting eggshells following a successful hatch or destruction of the nest. Chick survival was determined by visual assessment or by interpreting the female’s reaction to the researcher. Fledging success was determined 35-40 days post-hatch, based on visual assessment (spotlight surveys on two consecutive nights).

### ***Results***

The study was initiated in April 2009 and is designed to collect at least two years of pre- and four years of post-construction data, so findings reported here are preliminary.

*Lek use and size.* A total of 462 males were counted on all study area leks combined. The three leks closest (0.38–0.85 miles) to existing turbines were all active in 2009, the first breeding season after the turbines were erected. Of the 12 leks located within four miles of Simpson Ridge, mean lek size went down from 39 males in 2009 to 23 in 2010. All three leks within a mile of turbines were still in use three years later. While attendance was down, this decline corresponded to a similar trend at non-wind turbine-proximate areas.

*Nest success.* Nine nests were initiated within one mile of existing wind turbines; the four nests closest to turbines were located 130-486 m from the nearest turbine. Seventy-one percent of females initiated nests. Nest success was 37% in both 2009 and 2010. This is on the low side compared to other studies done in Wyoming over past 15 years, which have found success rates of 33-72%. Of the 18 nests initiated within one mile of wind turbines at the Seven Mile Hill project, four (22%) were successful. The primary cause of nest loss was predators (mainly mammalian).

*Brood success.* Early brood locations were obtained from hatch until June 30. Late brood locations were obtained from July 1 through August 15. Early brood success (first 14 days) was 100% in 2009, while fledgling success (35 days post-hatch) was 63%.

*Seasonal ranges.* Over 2,300 locations were obtained from the start of the study in April 2009 to June 2010 (slide #28). These data indicate the study area population is non-migratory. For 2009, for example:

- Summer (late June through September) – over 200 locations throughout the project area (slide #24)
- Fall (October 1 through November) – over 100 locations throughout the project area (slide #25)
- Winter (December 1 to early April) – over 200 locations throughout the project area (slide #26)

*Mortality.* Similarly, fatalities occurred throughout the study area (slide #27), mostly attributed to predation. (Three deaths were confirmed to be infected with West Nile virus.) Annual survival of adult females was 53% in 2009. Survival in 2010 (through mid-June) was 76%.

### ***Discussion***

Population trends as estimated from lek counts were consistent with somewhat downward trends observed in Wyoming in 2009 and 2010. Nesting propensity (the number of females initiating nests) was low relative to other studies conducted throughout Wyoming since 1994. Nest success rates were within the range of observed rates, but generally on the low side of the range for other Sage-grouse studies. Fledging success was on the low side of the range (63% with range being 60-80%). Annual survival (53%) was within the range of other studies.

Data presented here should be considered preliminary, and are not meant to provide a basis for forming conclusions about the potential impacts of wind energy development on Greater Sage-grouse. Sage-grouse continue to use wind project areas, but we need to look at the longer term data, in view of the fact that studies from the oil and gas industry do not show declines until as many as 4-10 years post-construction.

## Questions & Discussion

### ***Was a reference site used?***

Johnson: For Simpson Ridge there is a reference site near Rawlins, WY where telemetry studies have been done.

### ***What about the male Sage-grouse? Why did the study focus on females?***

Johnson: wanted to focus on reproductive impacts, so focused impact on females.

### ***Which mammalian predators are taking nests, and could development, e.g., roads, have increased predation?***

Johnson: We think it's mostly badgers taking nests, but we don't have any pre-construction data, so we cannot say whether predation has increased near the wind turbines.

### ***Was persistence of declining birds on leks from old birds with high site fidelity (consistent with expectation of survival) – thus no immigration once turbines were up?***

Johnson: All that we can say is that the leks were still active two years post-construction, and that the decline was regional. We would need more time to be able to say more.

### ***Were the slopes of the lines for the trends in lek counts within one mile of a turbine different from the regional trend?***

Johnson: We have not yet done any data analysis – this was just raw data. After March we will do statistical analysis.

### ***How did you measure nest success? Did you model it in Mark and if so, what factors were included in your candidate set?***

Johnson: Nest success was simply presented as the proportion of nests that were successful. Statistical analyses will be conducted at the end of the two-year study.

### ***What proportion of grouse reduction from year to year was due to mortality? What was the most common form of mortality?***

Johnson: Virtually all loss of radio-equipped hens was due to mortality rather than lost transmitters. The most common cause of mortality was predation; three deaths were positively attributed to West Nile virus.

### ***You state that it may take years to demonstrate an impact. Are there plans to continue this study?***

Johnson: We have a proposal to continue the study.

### ***How did you successfully create these partnerships with industry?***

Johnson: A study like this has implications for the whole western U.S. – it was an optimal location and opportunity, and we knew that it would be a collaborative effort. Circumstances facilitated collaboration and publication of data.

## ***Modeling Habitat Distributions of Bats Using GIS: Wind Energy and Indiana Bats\****

[Jason Jones](#), Tetra Tech, Inc.

(co-authors: Erik Jansen, Texas Tech University; Robert Friedel, Tetra Tech)

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**Research objectives:** 1) To highlight the utility of habitat models in reducing the potential impact to bats (particularly threatened or endangered species), which will, in turn, minimize scheduled delays and unexpected costs. 2) To underscore the importance of understanding animal behavior in estimating risk. 3) To provide specific recommendations (e.g., micro-siting, additional studies, project scheduling) for addressing potential risk to Indiana bats.

**Key terms:** Indiana bat, *Myotis sodalis*, habitat models, geographic information systems

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Are Indiana bats susceptible to collision with wind turbines? This question was answered recently when an Indiana bat collision fatality was confirmed at the Fowler Ridge wind energy facility. This finding has increased the scrutiny on this species, from the standpoint of both habitat and population impacts.

A better understanding of the potential distribution and movement of bats on the landscape is essential to minimizing collision impacts. Using remote sensing and Geographic Information Systems software, we present a modeling approach that evaluates the distribution of bat roosting and foraging habitat and potential flight paths at a landscape scale which may be used to assess the risk to bats from the development of a wind energy facility. In addition to the biological ramifications of an accurate risk assessment, this approach can minimize schedule delays and unexpected costs.

### ***Habitat models and relation to risk assessment***

The use of habitat models has a long history. Knowing where animals are likely to occur (behavior) can improve risk-minimization strategies. Traditional models focus on habitat patches, applying various attributes or factors to map the probability of species occurrence and therefore risk. There are fewer models that focus on movement of individuals among patches. This method applies what is known about the behavior and ecology of the federally endangered Indiana bat (*Myotis sodalis*) to predicting the areas where the species is likely to be during the breeding season, thereby highlighting the riskiest areas within a proposed project area.

### ***Germane aspects of Indiana bat ecology and behavior***

The Indiana bat is one of the least understood species within a group of organisms that is itself poorly understood. Within this poorly understood species we know more about some of its life stages than about others. We understand more about its summer residency period and its winter hibernation period than about its migration periods. We know that there is a degree of sexual segregation during summer – and that this relative and differential use of habitat will have bearing on population impacts.

For the development of habitat models that incorporate the behavior of individuals, the critical gap that we need to fill is our understanding about how bats move across the landscape among habitat patches.

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\* Slide presentation not available as part of this Proceedings.

Are they completely risk averse (no gap-crossing behavior) or do they move freely among these patches?

### **Habitat definitions**

A first point is to acknowledge simplifications made for modeling purposes. We have defined three types of habitat, as follows.

1. *Foraging habitat* - defined as perennial streams and any wetland at least 0.4 ha (1.0 acre).
2. *Roosting habitat* - any forest patch at least 4 ha (20 acres), and lone trees that fell within 15 m of these forest patches. These patches have to be within 500 m of water, or connected to a patch that is within 500 m of water.
3. *Commuting habitat* –designed to capture the potential movement of creatures across the landscape independent of patches they might be selecting for roosting or foraging. Defined as any forest within 300 m (1,000 feet) of suitable roosting habitat or previously identified commuting habitat.

### **Application 1 – construction avoidance areas**

Can we define areas within landscape where probability of impact to breeding Indiana bats is so low as to be negligible?

Using these habitat definitions, we can easily map to location of potential habitat and develop a suite of habitat-based recommendations (e.g., avoid removal of roosting habitat or do not site turbines in close proximity to foraging habitat). However, these recommendations do not incorporate the behavior of the Indiana bat (i.e., the movement among habitat patches). One solution is to create a construction avoidance area (e.g., 1000-ft buffer) around all potential habitat that accommodates the potential for this bat movement. If developers can avoid this buffered area, the potential for negative impacts to breeding bats will be greatly reduced. We've had success with this approach in FWS Region 3.

How can we refine this analysis? We can actually visit the site, take a look at these patches to see whether they actually represent the types of habitat that aerial analysis suggests they do.

### **Application 2 – evaluation of relative risk (in this case across two projects) – site selection aspect**

A second application would be to compare relative risk among potential projects. A simple comparison of habitat availability at a given project site can be misleading. In some case, the spatial juxtaposition of habitat patches and the potential bat movement corridors among these patches can lead to a higher assessment of risk that suggested by habitat availability alone.

### **Field verification**

Are these models useful? Radio-telemetry data collected in the Midwest in 2009 suggest that they are. Bats were observed using both our defined habitat patches and identified movement corridors. As a result, it appears that Indiana bats are willing to cross non-forested gaps during nightly foraging bouts in the breeding season.

### **Conclusions**

The results of our modeling indicate that risk to bats is not directly proportional to habitat availability or suitability, in part because risk is associated with areas where bats are traveling. This modeling approach will assist wind energy developers in making both large-scale (e.g., choosing between different development locations) and small-scale decisions (e.g., choosing where to locate turbines) aimed at

minimizing impacts to bats. Using habitat models can provide a cost-effective method for evaluating bat risk, satisfying requirements of United States Fish and Wildlife Service, and limiting the more intensive survey methods to projects that absolutely require them.

### ***Next steps***

We need to refine our modeling of gap-crossing flight behavior, improving our incorporation of the landscape context, perhaps developing statistical models.

These models are most useful when forest cover is not the dominant land cover class on the landscape (e.g., in the Midwest). The models would need to be updated for landscapes that are primarily forested (e.g., mountainous regions of eastern North America).

We need to incorporate similar strategies for modeling migratory behavior and spring and fall swarming behavior, which we should consider a distinct part of the annual cycle of these bats.

The critical step is going to be to integrate these habitat models with population models to look at long-term impacts.

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## Questions & Discussion

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### ***Why do your passage corridors not connect to your habitat polygons?***

Jones: We need to think about commuting habitat in functional terms, given the scale of the animal's movements. So it may be that there is a space or gap between two patches of habitat, but in functional terms they may be considered connected.

### ***What types of habitat connectivity models might you use for future analysis and what kinds of parameters (e.g., landscape features) might you use to determine landscape "friction" or resistance to bat movement?***

Jones: We don't know what the perfect existing model might be. There are a number of modeling approaches out there. I would prefer to see data from radio telemetry of bats guide the development of the predictive model. Let actual bat behavior tell us what the relevant connectivity concept is. There are a few measures that could be used, but the most relevant landscape metrics are those that are thought to be related to why bats might move from these patches, like where there are lots of things to eat.

### ***How do you propose migration should be addressed in the model?***

Jones: I don't think that migration can be addressed in this particular model, in that habitat requirements are far more flexible during migration than they are during the breeding and summer residency period. In that case we would have to resort to distance modeling of flight projections for bat movements at night and incorporate some energetics into linking possible stopover locations.

### ***Did you develop your habitat definitions in consultation with the regulators?***

Jones: The habitat definitions were developed using a series of sources, including the Draft Recovery Plan, active Indiana bat researchers, and consultation with FWS biologists in all regions where the bat occurs.

## ***Reproductive Success of Black-capped Vireos and Other Shrub-nesting Passerines in Relation to Distance from Wind Turbines***

[Caleb Gordon](#), Pandion Systems, Inc.

Shrub-Nesting Passerine (SNP) Collaborative: Kris Karsten and Amanda Hale, Texas Christian University; Greg Forcey and Bryan Suson, Pandion Systems, Inc.; Scott Turner and John Kuba, Turner Biological Consulting; Joe Grzybowski, University of Central Oklahoma; Harold Greeney, Yanayacu Biological Research Station

[Link to Presentation](#)

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**Research objectives:** Characterize the relationship between distance to nearest wind turbine and reproductive success in the federally endangered Black-capped Vireo and other shrub-nesting songbirds of the central Texas-Oklahoma region.

**(Null) hypothesis being tested:** There is no relationship between distance to nearest wind turbine and reproductive success in shrub-nesting songbirds of the central Texas-Oklahoma region. This hypothesis is being tested separately for six species: Black-capped Vireo, White-eyed Vireo, Painted Bunting, Blue-gray Gnatcatcher, Lark Sparrow, and Northern Cardinal.

**Key terms:** Black-capped Vireo, brood parasitism, gradient-impact analysis, indirect effects, Mayfield method, nest predation, reproductive success, Texas

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The Shrub-Nesting Passerine (SNP) Collaborative Research Project is a team of scientists and institutions headed by The Environmental Bioindicators Foundation and Pandion Systems, directed at understanding extent and nature of the impacts of commercial wind development on the fitness of shrub-nesting songbirds. In the central Texas-Oklahoma region, this focal species group is of particular interest because the breeding distributions of two federally-listed bird species, the Black-capped Vireo and the Golden-cheeked Warbler, are globally restricted to this ecoregion, and because this region is highly desirable from a wind energy development perspective.

This presentation reports the results of the first two field seasons of research conducted by the SNP Collaborative Research Project in 2009 and 2010, directed specifically at characterizing the relationship between the reproductive success of shrub-nesting passerine birds and the distance to the nearest wind turbine. This study provides the first rigorous scientific analysis of the potential indirect effects of wind turbine proximity on the reproductive success of birds. By characterizing nest success as a function of distance from turbines, we can address the potential efficacy of gradient-based mitigation measures such as set-backs and buffer zones.

### ***Methodology***

Our study focuses on reproductive success as a fitness measure, and uses gradient analysis to characterize impact. This was performed in 2009 for five non-listed shrub-nesting songbirds found within the Wolf Ridge Energy Center (Cooke and Montague Counties, Texas), and in 2010 for the

federally endangered Black-capped Vireo at the Horse Hollow Wind Energy Center (Taylor and Nolan Counties, Texas). We employed two parallel and complementary analytical techniques.

1. Conventional analysis of Mayfield's Daily Survival Rate (DSR) and related statistics
2. Information theoretic analysis of univariate and multivariate Mayfield logistic regression models that included distance to nearest turbine as well as additional potential explanatory variables, including a variety of vegetation and landscape variables that were also measured in the field.

The first step was to conduct a uniform search effort to find nests in the parcels of suitable shrubland habitat identified at each site. We then monitored each nest every 2-4 days from discovery until completion (fledging, depredation, or abandonment).

In 2009, we found and monitored 197 nests of the five songbird species, combined, and in 2010 we found and monitored 153 nests of Black-capped Vireo.

### ***Analysis***

How might wind turbines affect nesting success? There are many possible mechanisms; for example, they may affect the success of predators and parasites. Our metric was the daily survival rate (DSR), with +/- 95% confidence intervals. The methodology is not new, but we have different ways to analyze the results statistically. We used both the Mayfield Logistic Regression (Hazler 2004) and the Information-theoretic approach (Burnham and Anderson 2002).

### ***Results***

No statistically significant relationship between wind turbine proximity and reproductive success was found for any of the five study species, using any of the analytical techniques. Strong statistical evidence for a lack of such effect was produced for one species in 2009 (Northern Cardinal), and also for Black-capped Vireo in 2010.

In 2009, overall nest success numbers were low – 5.4% to 9% for all species except for the Painted Bunting, which had a success rate of 25.5% (slide #16). Both predators (snakes) and parasites (e.g., cowbirds that lay eggs in vireo nests) were likely important factors in low success rates observed at Wolf Ridge in 2009. Nest success of Black-capped Vireos at Horse Hollow in 2010 was higher, roughly 20%.

Slide #17 shows DSR as a function of nest distance from turbines for the five non-listed songbird species studies at Wolf Ridge in 2009, with near (red bar) defined as less than 300 m and far (blue bar) defined as more than 300 m from turbines. The black vertical lines give the confidence intervals. For all five species, the confidence intervals for the survival rates of “near” and “far” nests overlap, meaning we cannot reject the null hypothesis that distance is not significant. In this graph, the dashed horizontal lines delineate the inverse hypothesis. If the confidence intervals for both red and blue bars fit within the dashed error bars, then we can say that reproductive success is equivalent for near and far. In 2009, this was true only for the Northern Cardinal, for which we had the largest sample size (111 nests).

In 2010, we found statistical equivalence in near and far from turbine groups for Black-capped Vireo with respect to both nest predation effect (slide #26) and brood parasitism by Brown-headed Cowbirds (slide #27), though the equivalence was stronger for predation than it was for brood parasitism.

Information theoretic analysis of regression models for the 2009 dataset (slide #18), and for the 2010 dataset (slides #28-30, skipped in presentation) showed no indication that distance to turbine explains a significant amount of variation in reproductive success in any of the study species in either year at either site.

### **Summary of Results**

We did not see any evidence that distance to turbine has an impact on nest success of the five songbird species we studied in 2009, with respect to either nest predation or parasitism, but especially with respect to predation. The following caveats apply: this represents only one year of data at a single site, and the positive statement about no effect is limited to a single species (Northern Cardinal). Further research is needed to verify the robustness of this pattern, and to determine how well it can be generalized to additional species, years, and sites.

For the Black-capped Vireo studied in 2010, there was likewise no apparent influence of wind turbine proximity on reproductive success, although again this is based on observations at a single site during a single year, and a positive “no effect” statement is stronger for the predation effect than it is for the brood parasitism effect.

## Questions & Discussion

***How did you determine the distances of 300 m and 400 m to distinguish your “near” and “far” categories? Why was the distance different for the two studies, and how would changing those distances affect results? (For example, might the relevant distance be shorter – say, 100m?)***

Gordon: The distance categories that we analyzed were selected more or less arbitrarily to divide sample size in equal chunks. There is a number out there – 300 feet (~ 100 m) that was put out initially by the Fish and Wildlife Service. Most of our nests are farther than that – most are at least 70 m from turbines.

***Was sample size sufficient to analyze a smaller distance, and were there differences in habitat at the different distances from turbine?***

Gordon: The finer we slice the distance categories, the harder it is to do the statistics, because the sample size gets smaller. We did look at habitat effects to a limited degree, more in 2010 than in 2009. This told us a few things about habitat – but we were focused on what the impacts of wind turbines were on nesting success.

***Did you survey the predator community at either site? What were the most common predators?***

Gordon: We did not do any formal surveys of the predator community. Informally, we know that there are a lot of snakes!

***Can you say anything about how the nest success rates at these facilities might correlate to nest success in these species at other (non-wind) sites?***

Gordon: For 2009, the nest success at Wolf Ridge is low relative to published surveys. For 2010, about 20-23% nest success is within the range of what’s been measured elsewhere for Black-capped vireos.

***A daily survival rate of 0.899 is about 10%, which is very low (equivalent to “surviving” 21 days). How does this relate to nest success?***

***Doesn't DSR change over time from egg appearance to fledgling? Wouldn't percent survival from egg to fledging be a better integrated measure?***

Gordon: The daily survival rates we measured corresponded fairly well with nest success. A survival rate of 0.899 means that the nest has a 90% chance of making it until tomorrow. Does DSR change over time (eggs versus nestling stage)? Yes – note that these analyses are not done yet. There is a trade-off between how finely you slice your data and how much statistical strength you can bring to bear in the analysis. We considered analyzing DSR separately for egg and nestling stages, but ultimately decided it was more informative to lump these two stages into a single DSR value averaged over the entire period from egg-laying through fledging.

This issue is partly addressed in the modification we made to the Mayfield technique for the Black-capped Vireo analysis. For parasitism, we're only looking at the egg stage as the exposure period, whereas for predation, the entire egg-laying through fledging period is counted as exposure.

***As with grouse, could nest success decrease over time – is it possible that you might not see an impact in the population before three to five years go by? Do you think that the fact that the closest nest is 70 m from turbines is itself an effect of turbines on reproduction?***

Gordon: There might be a delayed impact, but if we're seeing those birds reproducing successfully now, that probably won't change over time. The closest nest being 70 m away is partly because the turbine area is clear – there are not many shrubs to nest in. There was no pronounced avoidance of turbine areas for nesting that we could see.

***Have you done a power test on any of these analyses? What sample size would be needed to see a difference?***

Gordon: I insisted on this initially, but our post-doc Kris Karsten eventually became convinced, and succeeded in convincing the rest of us that there were enough inherent problems with notion of power analysis, and that equivalence test was better way to get at the strength of the evidence that there is an effect.

***How do you think the repeated presence of researchers might have affected nest predation and parasitism?***

Gordon: This is old-school ornithology. The vast body of ornithological literature suggests that careful Mayfield monitoring of nests has less impact than you might think.

## ***Night Migration Concentration Areas in Michigan and the Great Lakes: Knowledge Important to the Siting of Wind Farms and Other Tall Structures***

[Joelle Gehring](#), Michigan Natural Features Inventory

(Co-authors: E.H. Schools, H.D. Enander, Michigan State University)

[Link to Presentation](#)

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**Research objectives:** 1) Use radar (i.e., NEXRAD) to identify areas in Michigan and the Great Lakes with concentrations of migrating fauna higher than surrounding areas over time. 2) Test whether areas of high concentration were randomly distributed in the landscape or clustered in specific areas.

**Key terms:** Great Lakes, landscape-level analysis, Michigan, migratory songbirds, NEXRAD

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The Great Lakes and their associated shorelines have a propensity for high, steady winds, making them ideal locations for wind energy development. A wind power classification map shows the high potential for wind energy development on and along the shorelines of the Great Lakes. The state of Michigan has more fresh-water shoreline than anywhere in the world, and features incredible habitat such as large dunes. The people of Michigan also highly value the Lakes for recreational, aesthetic, and cultural purposes. Portions of these shorelines are also of high value to migratory songbirds and bats, and several studies have documented localized migrant songbird concentration areas.

Rob Diehl found that birds are moving across the Great Lakes with as much frequency as they move across corn fields, and the shoreline is important stopover habitat. The FWS is generally suggesting that turbines be placed more than three miles from the Great Lakes' shorelines. We have to make such judgments with the best information we have, but we want to understand not just stopover, but also flight patterns and how that may impact appropriate siting.

The Michigan Natural Features Inventory is a group within Michigan State University Extension. We wanted to learn more about where birds – or any migratory target – are moving throughout the landscape, so that we can avoid putting tall structures in sensitive areas.

### ***Data collection***

In an effort to provide data and ensure these wind resources are developed sustainably, we used NEXt generation RADar (NEXRAD; WSR-88D) to quantify migration concentration areas in relation to the Michigan shorelines (Great Lakes of Superior, Michigan, Huron, and western portions of Erie). There are four NEXRAD stations located in Michigan, one on the Upper Peninsula (Marquette), one in Gaylord, one in Grand Rapids, and one in Detroit. All the data are archived, which facilitates research.

NEXRAD is useful for looking at larger trends across the landscape. It is used for weather, but also can be useful for determining bird/bat migration at large-scales. This type of radar is capable of identifying birds within a 120 km radius, and can be used to estimate the density of targets (e.g., mean number of birds/ km<sup>-3</sup>) in an area.

### ***Data analysis method***

We looked at archived data from April 21 to May 31 and September 1 to October 31, 2008, at 23:30 local time, which approximates the peak of nocturnal bird migration activity.

ArcGIS was used to spatially delineate migration concentration areas based on existing state level radar data. To analyze the spatial distribution of reflectivity values, we utilized a grid of points evenly spaced 500 meters apart across the state, and mapped that on the NEXRAD data pixels. The points were intersected with the radar polygons and each point was assigned the reflectivity value of the corresponding radar polygon.

One challenge with NEXRAD data is that you have to take into account the curvature of the earth. To deal with this we created a 30-km band outward from the radar site and compared data within those bands.

After removing from the analysis those days characterized by weather events or dominated by insects, we looked at those points that exceeded a 95% reflectivity threshold – i.e., points that had a lot of bird/bat targets – converted to this to a raster dataset, and summed the data over time. We used Moran’s Index to determine if there were patterns of migrant bird/bat use over the landscape were clustered, random, or dispersed.

### ***Analysis of findings***

Upon analyzing the distribution of radar reflectivity values, we found that most areas had low bird densities over time. After identifying those areas with high concentrations of migrants, we tested their spatial relationship to the Great Lakes’ shoreline. Analysis of these data determined that some portions of the Great Lakes’ shorelines supported high concentrations of migrants while others did not, and that not all high concentration areas were directly associated with shorelines. We also found differences between the spring and fall migration seasons.

The Index did show that data were clumped, and that clumps were statistically significant. So, for example, we are not seeing a high density of birds in the “Thumb” area. This is significant because the Thumb is considered a good place for wind development.

We did see some clumping in the northern part of the state (Petoskey). The data are as useful from the Marquette NEXRAD on the Upper Peninsula. We do see clumping along the Lake Michigan shoreline from the Grand Rapids NEXRAD station.

### ***Next Steps***

These data are useful for identifying those areas of potential high risk for the development of wind energy resources. Our research and mapping efforts provide information and recommendations that are based on sound science, creating a product that can be utilized by wind developers, local planning and zoning commissions, and natural resource agencies during the wind farm planning and review assessment stages.

We hope to integrate these data into other mapping efforts so that we can practice better siting, not only with wind turbines but with all tall structures. We will add additional migration seasons, include additional radars, and continue to use 20 km bands, because they were more successful than the wider bands.

## Questions & Discussion

***The radar data do not seem to support 3-mile buffer zone for two of the three radars you looked at. Please clarify what the data show relative to the idea of a 3-mile buffer zone.***

Gehring: Agencies were aware of possibility that it might be more site-specific as opposed to just a 3-mile buffer zone for the entire coast. We also see developers doing point counts during migration periods within the coast line buffer zone.

***Do the patterns of high use areas from NEXRAD match known important habitat types for birds in Michigan?***

Gehring: We are mainly focusing on the shoreline question at this point. Could we also look at riverine corridors? Potentially yes, but we have not been focused on stopover habitat, but rather flight times.

***Could the lack of birds in spring in the Thumb be due to birds stacking up on the S. Lake Erie shoreline and not reaching the Thumb until well after your target hours (23:30)? Or could it be because you are not getting good radar data?***

Gehring: We know we're not getting very tip of thumb with radar coverage. We did go out 120 km beyond the tip of the Thumb to try to address that. There are birds congregating on Sandusky shore, so we could look at later periods in the evening or look at areas south of thumb in the radar data.

***How do you think your results would change if you used as a metric the number of days a pixel was in the top 10%? In the top 50%?***

Gehring: The more days of data we include the more we lower our resolution. We may lose the hot spots to the broad front nature of migration as documented by Rob Diehl. We don't see a line of birds along the Mississippi River; it's more that they cover the state like a broad blanket. If we analyze the data in terms of corridors, we will lose some of the data.

***Most reflectivity was green, representing one night. Were there areas of more intense migratory activity?***

Gehring: Green represented areas with one night of high migration intensity. The warmer colors, which were more limited, represented the areas with more nights of intense migratory activity.

***Why were the targets on most of the radar images grouped towards the inside of each ring?***

Gehring: This is an artifact we tried to get rid of by going to narrower (20 km) bands. NEXRAD shoots over the birds because the surface of the Earth is curved.

***Can you tell the altitudes of the birds you looked at from Radar?***

Gehring: Currently we are unable to do that, though I understand it is possible.

***Was the data Level II or Level III data?***

Gehring: We used Level II data.

***How did you distinguish bird targets from other biomass targets such as bats and insects?***

Gehring: We cannot distinguish between birds and bats with this data, hence referred to them as migrating targets. We eliminated from analysis those days which were dominated by insects – these days were identified by the speed of the targets in relation to the winds aloft data.

***Did you use precipitation mode or just clear air mode?***

Gehring: We used clear air mode only.

***What do we know about landscape level year-to-year variation in song bird migration?***

Gehring: We need to know more, and would like to add seasons to these analyses. We don't know enough about birds, and certainly not enough about bats. For example, in our communication tower work, we never found Blackpoll Warblers in spring, but always found them in the fall. So we know that spring migration patterns differ from fall, and suspect there are differences year to year simply because of variation in weather patterns.

***How does one go about obtaining this NEXRAD data?***

Gehring: NEXRAD data are available online. Some sites are easier to get than others. We used data from the NCDC website.

***Can NEXRAD help map entire areas of the offshore Great Lakes, or will analysis be limited?***

Gehring: Some information is available. NEXRAD sites from rest of the Great lakes area can be added in relation to potential offshore Great Lakes development.

# Day One – Wrap up Discussion

## Moderator: Abby Arnold, Kearns & West

Participants were asked to share observations or comments at the end of the first day's presentations. Themes that emerged included: collaboration; the quality of the research being done and presented; concerns related to cumulative impacts and the need to translate research findings into best practices on the part of permitting agencies. Specific comments:

Abby Arnold: We are starting to see a real shift in the way people think about sharing data. The American Wind Wildlife Institute (AWWI), which was founded to support collaborative research, has established a pilot research database that gathers data from wind-wildlife studies, making it available for analysis in a way that protects the confidentiality of industry partners.

Jason Jones: We have been talking a lot about collaboration, but one aspect I haven't heard discussed is collaboration within and across the consulting community. As competitors, we need to take advantage of our own intellectual capital, but in the interest of transparency and moving the agenda forward, it is essential that we find ways to collaborate.

Dick Anderson: I am encouraged by the amount of work that's going on about bats. It took over a decade to get to this kind of momentum going on bird research; the momentum on bat research is stronger.

Rob Pastorak: As a newcomer to this forum who has been involved in ecological risk assessment for a long time, I am impressed with the level of detail and the quality of the presentations. I see a need for standardization and protocols for measuring fatality among sites. Developing standard and consistent metrics and protocols should be a high priority.

Abby Arnold: NWCC did develop a metrics and methods guidance document, which has been reviewed/edited a couple of times – the next edition will come out by the beginning of 2011. It is written more like a textbook than a set of guidelines.

Lynn Sharp: We need to keep cumulative impacts on the priority list for discussion – particularly as we work towards AWEA's goal of 20% renewables.

Rebecca Thompson (URS Corporation in Boise): We are collecting really good research, but there are a lot of permit applications going to land management agencies, and science hasn't caught up to the permitting process. What do we do?

Rebecca Efroymson (Oak Ridge): We've heard a lot about studies of impact from commercial scale developments, but we don't get any information about how residential and community-scale developments may impact wildlife.

## Session 3: Impacts to Wildlife and Behavior, Part 2

**Moderator: Dick Anderson, California Energy Commission (retired)**

The following presentations are a continuation of Session 3: Impacts to Wildlife Habitat and Behavior.

### ***Big Game Impact Assessment: Lessons Learned from Natural Gas Development in Wyoming***

[Hall Sawyer](#), WEST, Inc.

[Link to Presentation](#)

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**Research objectives:** 1) Evaluate how big game respond to different types of energy development (i.e., indirect habitat loss); 2) Determine how to identify and prioritize big game migration routes to minimize potential impacts of energy development.

**Key terms:** avoidance, Brownian bridge, indirect habitat loss, migration routes, movement corridors, mule deer, stopover sites, Wyoming

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Increased levels of energy development across the Intermountain West have created a variety of big game and habitat management concerns. There are important differences between natural gas and wind energy development in terms of infrastructure and habitat disturbance, but they raise some of the same questions about how we evaluate and avoid or mitigate impacts. Two of the more pressing concerns include:

1. *Indirect habitat loss* – How do big game respond when critical habitats (e.g., winter range) are affected by development (avoidance impacts can be considerably larger than direct loss of habitat)?
2. *Migration route impacts* – Can we identify and prioritize animals' migration routes to minimize potential impacts?

This presentation illustrates how these concerns have been addressed with the use of global positioning system (GPS) collars, state-of-the-art statistical methods, and before-after impact studies associated with gas development in Wyoming.

#### ***Indirect habitat loss***

In the case of indirect habitat loss, we want to make an inference about habitat response of animals within a defined area. Typically we capture and outfit animals with GPS collars. Slide #3 shows different types of mule deer locations. We can use this GPS data to estimate resource selection functions (RSF) – i.e., the probability of use as a function of different habitat characteristics (slope, distance to road, etc.) We can use RSF to predict animal use of habitat – e.g., lower deer use close to well pads, higher deer use farther away.

Ideally, baseline data are needed. Slide #7 maps predicted deer use before and three years post development.

### ***Migration impacts***

Migratory big game outnumber their non-migratory counterparts by several orders of magnitude. Western Wyoming supports 100,000 mule deer, most of which are migratory. Lack of understanding about these animals' migratory routes limits our ability to assess impacts or develop effective land-use plans. A common perception is that animals simply migrate along one, well-defined route. However, because the summer range is much larger than the winter range, most big game populations utilize multiple routes.

Advances in GPS technology have been helpful in plotting start and end points as well as interim positions for individual animals, but delineating migration routes and making population-level inference has remained a challenge.

A new methodology (Brownian Bridge movement model, described in Roel May's presentation) resolves these problems by providing a utilization distribution (UD) associated with the route. UD values can be categorized as high, medium, low to differentiate movement corridors from stopover sites. Individual UDs can be combined to estimate a population-level migration route.

Slide #12 shows a natural gas development area with multiple routes radiating from a relatively small winter range to larger summer range. Two of the proposed gas sites in map overlap with routes.

### ***Movement corridors versus stopover sites***

Why differentiate between movement route and stopover sites? If stopover sites are differently affected by development than movement corridors, we should manage these two types of migratory segments differently. A road, for example, could be built across a migration route provided it doesn't pose a complete barrier to movement. In the case of a stopover site, it is more important to minimize habitat loss and human disturbance.

Slide #15 shows a refined version of the conceptual model, with routes shown branching from the smaller winter to the larger summer range, and stopover habitat differentiated from corridors.

### ***Brownian bridge approach***

How do we prioritize among multiple migration routes, given that it is unlikely all of the routes will be protected? A Brownian bridge approach allows us to see which routes are used more than others. Map (slide #16) shows that some route segments are used by a larger proportion of the population than others.

### ***Summary***

1. Indirect loss and behavioral response (avoidance) can be assessed using multi-year GPS study.
2. GPS data can be used to estimate population-level migration routes and to distinguish between stopovers and movement corridors.
3. Within population-level migrations, routes can be prioritized using a Brownian bridge approach.

These methods are applicable to any migratory species – from osprey migration along the East coast (minimize collisions with Air force jets) to manatee movements along coastal waters (versus recreational boating).

## Questions & Discussion

***Could the Brownian Bridge model be used with radio telemetry data if GPS data could not be obtained (e.g., for small migratory species)?***

Sawyer: It is most applicable to animals for which you can obtain time-specific location data. If you are observing animals, you could get what you needed to know about movement from point A to point B from observation.

***Any comments on the intensity of effort it would take with radio telemetry (i.e., # of data points) to discern movement patterns and stopovers versus movement corridors?***

Sawyer: One of the biggest questions is what frequency of data point is needed? The more the better, obviously, but it depends on how fast the species moves, the distance traveled, the frequency of data collection, and tortuosity of movements. For example, taking data from an albatross every seven minutes – that bird flew over 1200 miles, and we ran into computational limits trying to crunch the numbers. There should be work coming out in the next few years that will help us get at those answers.

***How was the summer area delineated for the population-level model (white dashed lines) – convex polygons?***

Sawyer: The convex polygons delineate summer ranges based on individual animals we tracked. The purpose of that delineation was to illustrate point that summer ranges are much larger than winter ranges.

***What was the cost of an analysis such as the example on the gas field, including the GPS radio tagging and analysis, assuming a 1- or 2-year study?***

Sawyer: Cost varies for most of the oil and gas work – with big game they can carry large transmitters that can last up to three years. The big upfront costs are for capture and collars, but then the cost to maintain is much lower. Risk analysis was expensive because we were developing the analysis procedure, but now that the code is available, that cost is much less. I would say about \$75,000/year.

***Are predictive maps ground-truthed? And is there habituation of animals after active drilling and completion of construction work?***

Sawyer: All of our models are spatially explicit. Regarding the acclimation of mule deer, we're now in the tenth year of study, and seeing no evidence of acclimation. Having said that, we recognize that not all pads are the same. Some generate a lot of vehicle traffic or have other activity going on. We have seen deer avoid all pads, but the less activity around the pads, the less avoidance.

***How does the Brownian bridge utilization distribution (UD) technique account for spatial autocorrelation in the GPS dataset?***

Sawyer: The great thing is that the technique requires correlated data, because it uses successive locations. So we don't have to worry about the autocorrelation problem.

***What is the population status of the mule deer population, and (how) has it changed since your study began?***

Sawyer: There are two different areas – we are now in our tenth year, and have been doing abundance counts for nine years. If we look at point estimates, population has declined 60%. A more conservative estimate is a 39% decline.

***What are situations where a Brownian bridge is or is not appropriate to understanding animal movement?***

Sawyer: This is a new method, so we are still getting a sense of that. It makes sense when we have frequent GPS locations and not a lot of missing observations. When our fixed locations are not frequent enough, then the statistics fall apart. But if you have the data, it's a great tool.

***What are differences in activity levels (etc.) between wind and oil and gas?***

Sawyer: In general, gas development requires higher levels of traffic and human disturbance in both development and production phases.

***Do you have any quantification of the avoidance distance? Looked like half-mile total avoidance, and two miles to heaviest use.***

Sawyer: In sagebrush winter ranges, mule deer tend to avoid well pads by 2-3 km.

***What physical/habitat characteristics are unique to the stopover sites? Are the features of the stopover sites distinct from those of the migration routes?***

Sawyer: Preliminary research suggests forage quality and foraging opportunities differentiate stopovers from other segments along the migration route.

***How permanent are stopover sites? Will they change with grazing pressure or climate? If so, over what period?***

Sawyer: In general, bird biologists have done a lot more in the area of migration routes and stopover sites, and the ungulate biologists are catching up. Areas with higher forage quality tend to be consistent from one year to the next and spring and fall alike.

***Are there any long-term habitat use data sets that suggest habituation to disturbance sources?***

Sawyer: There are situations where big game may acclimate to disturbance, but it depends on the species, the type/degree of disturbance, the vegetation/topography, and whether the population is hunted or not.

***Do these avoidance patterns persist over time? What is the human activity level at these sites post construction? What are habitat changes that occur with development?***

Sawyer: Avoidance patterns in sagebrush winter range have persisted for 10 years and counting. Traffic levels at drilling pads are about 80 vehicles per day, while producing pads average about seven vehicles per day. Loss of shrub communities is the primary habitat change that occurs in mule deer winter range.

## ***The Costs of Chronic Noise Exposure for Wildlife\****

[Jesse Barber](#), Colorado State University

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**Research objectives:** Demonstrate: 1) the geographical extent of anthropogenic noise; 2) the importance of sound to intact ecological function; 3) recent evidence showing impact of anthropogenic noise on animal behavior and community structure; and 4) the role of wind energy facilities in altering natural soundscapes.

**Key terms:** acoustical fragmentation, anthropogenic, chronic noise, masking

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Decades of research have shown that anthropogenic infrastructure associated with high levels of noise, such as roads, alter animal behaviors and distributions. Recent work strengthens the evidence presented by road ecology studies and indicates that chronic noise exposure changes foraging and anti-predator behavior, reduces reproductive success, alters animal density and shifts community structure. The goal of this presentation is to place wind energy generation in the context of other anthropogenic sound sources.

### ***How animals use sound***

Acoustically specialized species that depend heavily on current natural ambient conditions include northern harriers, owls, frogs, gleaning bats, and several songbird species. Every 3 db increase in noise can reduce an animal's listening area by 50% for signals within the frequency band of the noise (see Barber et al. 2010, Box 2 for details), and it is difficult to predict the cascade of ecological consequences from increased sound levels. Keep in mind that the sound ecology involves not just one animal talking to another, but lots of animals talking to lots of other animals. Salamanders, for example, use frog sounds to choose ponds.

The most important times for acoustically-mediated behaviors (both communication and hunting/anti-predator behaviors) occur during dusk and dawn.

### ***Anthropogenic noise sources***

Anthropogenic noise penetrates natural landscapes to an extent that we may not realize. Very low frequency jet noise, for example, can be heard in the Yosemite backcountry 70% of the time. Similarly, air tourist noise can be heard in a Grand Canyon backcountry site, and traffic noise can be picked up in Rocky Mountain National Park. Transportation modeling shows that 83% of the land in the continental U.S. is within ~ 1 km of a road.

Wind turbines also are a source of noise. Most of the modeling of wind turbine noise is done because of human complaints. Existing and commonly used modeling algorithms for sound propagation have not been developed with wind turbines in mind. Atmospheric stability (vertical gradients in wind speed and temperature and atmospheric turbulence) can dramatically impact sound propagation and are not factored into the models.

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\* Slide presentation not available as part of this Proceedings.

### ***How animals respond***

There is a wealth of evidence showing that animals adjust the temporal, spectral, intensity and/or redundancy characteristics of communication signals in response to added background noise. Grey tits, for example, raise their voice frequency in the city and change song to compensate for background noise. Other adjustments have been documented in birds, primates, cetaceans, amphibians and one squirrel.

Other behavioral adaptations to anthropogenic noise have also been documented, and noise has been isolated from other factors (e.g., edge effects) as the critical impact.

- Squirrels underneath turbines have been shown to be more sensitive to external stimuli (increased vigilance).
- A New Mexico study found fewer species at a treatment site than at the control site. Species that were nest predators avoided the louder site, so other species favored it.
- Intermittent (road) noise has been found to have a stronger effect than continuous noise on Sage-grouse lek attendance, but intermittent road noise has similar noise profile to that of a wind turbine.
- Gleaning bats always choose the quieter area to hunt. Saw-whet owls may be similar.

The case of gleaning bats is an important reminder that collision impacts are not the only concern we should keep in mind. Gleaning bats are difficult to detect with acoustic monitors, and because they fly low, they are less susceptible to collision with turbines. Yet their behavioral response – avoidance – means that their search time and energy that goes into finding a quieter area to hunt is increased, which may have very real consequences for their success.

These examples all pertain to terrestrial development, but the same questions apply in the marine environment.

## Questions & Discussion

### ***What are the general thresholds of effects to terrestrial wildlife groups for avoidance/chronic effects (in dBh – decibels)?***

Barber: There is a lot of variation across studies. Road ecology studies estimate that impacts begin in the 40 dBAs (24 hour Leq—a sound level integrated across the day). Some species respond in the high 30s. Impacts can be found about a km away from compressor stations.

### ***In ocean ecosystems, sound thresholds exist to prevent harassment of organisms. Do any thresholds exist for terrestrial ecosystems? If yes, what is the threshold (dBs)?***

Barber: Most anthropogenic noise impact studies have focused on the direct impact of a discrete incident like a jet flying over a nest, not chronic noise level impacts.

### ***Reduced listening area – domes getting smaller – talk more about this. How dramatic at 10 dB over ambient noise levels?***

Barber: Sage-grouse calls are within the frequency band of anthropogenic noise. The listening area (dome) model focuses on the masking component of noise, whereas Jessica's (Blickely et al. in review) research shows that intermittent noise has bigger impact.

***The A-weighted scale is usually used to evaluate impact on human receptors. Is this the most appropriate scale to evaluate wildlife receptors?***

Barber: A-weighting seems to work well for birds but for many species, using a human-centric frequency weighting is a poor approach. The best technique is to collect unweighted sound levels.

***Why or how do daytime assessments underestimate noise?***

Barber: They do not account for changing atmospheric conditions at night.

***You describe immediate direct and indirect noise impacts, but can you explain or generalize if species tend to adapt or acclimate to the noise over time?***

Barber: The red fox, for example, is an urban adapter – some species adapt, and some are very sensitive. The problem is that we don't know enough about which species are sensitive. We can't tell by looking at carcasses.

***Any thoughts and suggestions on how FWS should address noise issues in evolving service draft wind guidelines? (Noise impacts were not addressed in the FAC recommendations.)***

Barber: I would suggest using this body of literature as a guide. Windy areas tend to be louder, so development might not be an issue. Turbines on ridge lines will increase sound levels in previously quiet pockets of rolling terrain. Need good noise monitoring methods.

***Do you think it would be feasible to broadcast wind turbine noise at a site before construction to determine potential noise effects on birds and bats?***

Barber: Yes, we are working on that. It requires a tower and a lot of power.

***Have studies been done that are long-term enough to evaluate whether animals acclimate to chronic noise and return to an area?***

Barber: Road ecology literature is the strongest body of knowledge, and there has been some meta-analysis that suggests that there is a 1-km impact for birds, and a 5-km impact for mammals.

***Compare adverse effect of bird/bat avoidance of a wind facility versus benefit of lower collision mortality as a result of such avoidance.***

Barber: Species that are avoiding turbines because of noise are not likely to be high flying species threatened by collision. It is possible that some birds are kept away that might otherwise be killed. Clint Francis' New Mexico work is important. What he found was not an overall change in nest density, but changes in communities. If you just pick a few focal species, you may miss the overall impact.

***Pre- and post-construction bird surveys in eastern forests have focused on diurnal songbirds. Does existing acoustic data justify inclusion of owl surveys in forested landscapes, or landscapes that include forest patches of sufficient size to support owl pairs?***

Barber: Yes – the saw-whet studies I've worked on are lab studies – we do not yet have field data to know whether it's the same in the field.

## ***Interactions between Migratory Birds of Prey and Wind Turbines: Insights from Novel High Frequency GPS-GSM Telemetry***

[Todd Katzner](#), WVU and Cellular Tracking Technologies

(Co-authors: Trish Miller, Carnegie Museum of Natural History and Pennsylvania State University; Michael Lanzone, Cellular Tracking Technologies and the Carnegie Museum; David Brandes, Pennsylvania State University; Robert Brooks, Lafayette College; Jeff Cooper, Virginia Department of Game and Inland Fisheries; Charles Maisonneuve and Junior Tremblay, Ministère des Ressources naturelles et de la Faune; Kieran O'Malley, West Virginia Department of Natural Resources)

[Link to Presentation](#)

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**Research objectives:** Evaluate potential impacts of development of wind energy facilities on migratory birds of prey; identify potential mechanisms for mitigation of those impacts. Test hypotheses about flight behavior of raptors, specifically related to altitude, ridge fidelity and age-related movement patterns.

**Key terms:** Appalachian ridgelines, Golden Eagle, migration routes, Pennsylvania, telemetry

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Very little has been done to date in the Eastern U.S. to look at the impact of wind energy development on migration routes. The Appalachian Mountains attract more hawks and hawk watchers to Pennsylvania than anywhere else in the United States. Raptors fly down these ridges, using orographic lift (upward deflected air currents) to facilitate migration. Wind energy targets the same air movement and ridgelines.

Radar pictures are great in that they give you an idea of how animals are moving across a landscape, but they are limited by the position of the radar instrument and thus the duration that they can follow an individual animal. Golden Eagles (*Aquila chrysaetos*) migrate over routes that are hundreds of miles long. This study focuses on telemetry and modeling to understand eagle response potential to climate, topography, habitat and turbines.

We chose to look at Golden Eagles because they are large (which is helpful when it comes to developing a telemetry system), migratory, and susceptible to wind turbine collisions. These birds breed in Northeast Canada, migrate through Quebec and Northern New England and Upstate New York, and winter from New York State down to Georgia. We put telemetry units on 30 birds.

Our goal was to be able to develop predictive maps of the region showing relative risk to birds from potential development of wind turbines. To do this, we used two types of telemetry – hourly and 30-second data – and a two-step process that looked at both:

1. Broad-scale movements and decisions
2. Micro-scale movements and decisions

Satellite telemetry units collect hourly (GPS) data which is sent via satellite. These are highly accurate data that allow us to look intensively at how eagles are moving over ridgelines. We wanted to look at

the big picture (on a continental scale) and at micro scale to see how birds respond to changes in topography, weather, etc. GPS-GSM telemetry systems collect GPS data at much more frequent intervals – 15-minute or 30-second intervals – and send these data via the mobile phone network.

Slide #5 shows Golden Eagles moving south from Quebec to West Virginia. The paths of eight birds are shown. Note that while the birds use a wide part of Canada, there is a funneling effect as they hit the Pennsylvania ridges. A map showing a count of migrants map shows where the highest risk is – a narrow corridor in South-central Pennsylvania which is also a target for wind energy development. Clearly, we have to proceed with extreme caution and use of our modeling results to avoid collision impacts.

One metric that can be used in looking at risk exposure for migrating birds is the degree of “wandering” or “sinuosity” – i.e., the difference between the straight line distance from point A to point B and the actual distance traveled. We compared the sinuosity indices of younger and older birds, to see how risk exposure differs. It is clear that adult birds (shown in blue on slide #7), know where they are going, while younger birds (shown on right) wander a lot more. Again, however, when the birds get to Pennsylvania, they all funnel into the ridgeline and move linearly using the orographic lift.

We also looked at how weather impacts migratory patterns. Honing in on this Pennsylvania corridor, David Brandes simulated different wind conditions and looked at migratory patterns. As the wind shifts from SW to SE, northbound bird flight paths become more concentrated.

Slides #11 and 12 show examples of birds thermalling, bumping up to catch the thermal and then gliding, going back up and then gliding again. This kind of high frequency GPS-GSM telemetry slide is helpful for understanding where birds are going to be at risk along the ridgeline.

### ***Analysis of GPS data***

For our first-cut analysis we focused on spring migration, classifying flight behavior as thermal and non-thermal. Input variables included: climb rate (*m/s*), change in altitude (*m*), speed (*kph*), change of heading (*deg*), actual distance, expected linear distance. We saw more birds using thermals, fewer following direct flight paths when they were outside the ridges. When flying along linear ridges, flight lines are long and straight (less thermaling).

Comparing the area of eagle use and a wind resource map, there clearly is overlap. Moreover, we can see that about 50% of the time when eagles are close to high wind areas, they are flying fairly close to the ground (200 m agl).

In summary, Golden Eagles’ migration patterns are influenced by age, topography and weather. High-frequency telemetry studies lead to significant insights into migratory behavior. These studies show us that eagles can be at risk from turbines when on migration, but that this risk can be modeled, and these models can help us to mitigate risk to birds.

***Given that maximum wind turbine heights will range from 120 to 150 m, how specific is your data on Golden Eagles flying at less than 250 meters?***

Katzner: The data are pretty good – with the current platform for high-frequency telemetry we can tell you in horizontal plane exactly how accurate, and the next generation of telemetry will be able to tell you exactly how accurate in vertical plane. Our feeling is that we are accurate to within a couple of meters. When you look at thermalling images, you get a sense of precision because of the clarity of the images.

***Do you have to have cell coverage to gather data?***

Katzner: Cell coverage is not needed to gather data, but it is needed to transmit the data. We got four months worth of data all at once because one of the eagles had spent those four months in a small area out of cell coverage. You can program the units not to try to transmit when out of cell coverage so as not to run down the battery.

***How far were the micro-transmitters (cell-phone technology) able to transmit?***

Katzner: Their range is similar to that of a mobile phone.

***What was the weight of these transmitters, and how long before the technology is applicable to songbirds?***

Katzner: Weights are currently about 70-100 g, but we expect to have a 50 g unit out next year. It will be a few years at least before they are small enough for songbirds, probably longer.

***What is the cost and lifespan of the 30-second transmitters? What was the estimated total cost to gather and analyze the migration data you presented?***

Katzner: These are solar-powered units, and we expect them to last as long as the batteries last, about 3-5 years. Cost is a little less than satellite telemetry, about \$3000 /unit and \$4-500/year for data. We have had funding from about ten different sources over the past five years; the overall cost for whole project is a couple of hundred thousand dollars.

***Were the data sets derived mostly from 8 deployed GPS units, or a combination of the original 30 units?***

Katzner: Data were derived from 15 satellite units and 15 high-frequency global system for mobile communications (GSM) units.

***You mentioned that some of the marked birds did not have good enough data – why not?***

Katzner: For the birds with satellite data, we have hourly data, and we can't tell much about how a bird is moving down a ridge with hourly data. It's difficult to model. When we get 30-second data (from the GSM telemetry units), we can understand how they're responding to topography, weather, etc. We do get a few gaps in the data, but those are being worked out.

***Over what period of time (weeks, months) are birds migrating? Is the migration period a different length for spring versus fall?***

Katzner: Golden Eagles are a late fall and early spring migrant. The bulk of passage occurs in late October-November into early December, and then late Feb-March. Spring migration is fast – adults want to get up to breeding territories.

***Have there been any fatalities of Golden Eagles in any Appalachian wind power projects?***

Katzner: Not to my knowledge – in fact there have been remarkably few fatalities, although there is growing concern for cumulative impacts if you get facilities over an 80-mile stretch. Displacing these birds will impact their migration.

***Did you find any mortality of your eagles – if so, what were the sources?***

Katzner: Incidental trap mortality appears to be important to Golden Eagles in the eastern U.S., as does lead poisoning.

***How does survivorship of collared individuals compare with wild birds?***

Katzner: Whitefield and Matters have done some work on this in Scotland. This is a little controversial because of re-analysis of data. The general consensus is that the transmitter doesn't have impact. If you trap a bird on a nest, the eagle will not use that nest site again. We're pretty confident that we're seeing low impacts from putting telemetry units on birds, but it depends on the skill and experience of the person who puts the transmitter on. If it's done right, and the transmitter is scaled to the size of bird, there is no problem. There were some early studies of much too big transmitters being put on peregrine falcons. Transmitters are smaller now.

***What ultimately happens to the unit attached to the Golden Eagle? Does it eventually fall off, or is it permanently attached to the bird?***

Katzner: Some people use cotton thread to sew a harness, with the expectation that the thread will degrade eventually and the unit will fall off. When I attach a unit, my intention is that it will remain attached for the life of the bird. I don't want it falling off inadvertently and possibly injuring or constraining the bird.

***Were any eagles flying through or over existing wind farms, particularly in New York or Pennsylvania where it appears they may have done? If so, what type of flight behavior did you record?***

Katzner: We did have one or two eagles fly close to turbines, and we observed behaviors, but because there were so few instances and no repeated pattern of behaviors, it is impossible to interpret these data in a meaningful way.

***Have you attempted to overlay the fine scale visual representation of eagle flight behavior with known wind facilities on the Allegheny Ridge (e.g., as with Ron Larkin's use of Google Earth)?***

Katzner: Not yet, but we plan to do so.

***Would the corridor to WV change if collaring occurred in the wintering range instead of the summer range? (In other words, are the spring migration routes different from fall?)***

Katzner: To some degree yes. The corridor we observed is impacted by where we sample. We are trapping birds this year in central Virginia to see how this changes the overall interpretation of our data set.

***Your study has empirical information in the existence of thermals through eagle behavior. It didn't appear that you actually measured vertical winds (thermals). How will your risk model predict behavior based on wind measurements, rather than locating thermals from eagle flight behavior?***

Katzner: This presents challenges, but it is possible to model where we expect thermals to occur, and we will incorporate those weather models into our ultimate predictive models of eagle movement.

***Your model validated that eagles varied their paths according to wind direction. Was that feature not an assumption built into the model? Why not show actual evidence?***

Katzner: The model allows us to simulate many thousands of flights. We have only about 20 actual migration pathways from birds, so the actual evidence is very limited – that is why models are useful.

***Can your methodology and analysis also be useful for wind development where there isn't a "channeling effect" like there is along the ridge in Pennsylvania? Where flight patterns are distributed?***

Katzner: Modeling of flight behavior can be very useful to understanding animal movement and predicting how eagles and other wildlife will move through a landscape, and thus when they will be at risk from potential turbine or other development. The particular models we are building are site-specific, but other models could be built for other sites.

***It appeared on one figure that heights were 600-800 m – is that flight height above ground, or elevation? What is average above-ground flight height detected?***

Katzner: Altitude above ground level (agl) varies according to weather and region.

***While your landscape analysis focused on Pennsylvania, you have collected valuable telemetry data for other states and provinces. Do you have plans for eventually doing landscape analysis for the whole of the two major migration routes you have identified (Gaspé and northern Quebec), or for collaborating with other entities with specific geographic interests?***

Katzner: If funding is available, we would love to expand our modeling efforts to other regions.

## ***Comparison of Pre- and Post-construction Bald Eagle Use at the Pillar Mountain Wind Project, Kodiak, Alaska, Spring 2007 & 2010***

[Lynn Sharp](#), Tetra Tech EC, Inc.

(Co-authors: Christina Herrmann, Robert Friedel, Karl Kosciuch, Portland, Oregon; and Rich MacIntosh, Kodiak, Alaska)

[Link to Presentation](#)

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**Research objectives:** Quantify Bald Eagle use pre-and post-construction at a small wind project in Alaska; examine flight paths to determine if there are any changes post-construction; determine if birds avoid turbines when using topographic features

**Hypothesis:** Turbine construction and operation would not affect Bald Eagle use of the area and flight behavior (i.e., no avoidance).

**Key terms:** Alaska, avoidance, Bald Eagle, behavior, Kodiak Electric

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We know that eagle fatalities occur at wind farms. Golden Eagle fatalities have been widely documented in California, Wyoming, Oregon, and Washington. Bald Eagle fatalities reported to date, however, are rare. (There is one public record of a Bald Eagle fatality in Ontario, Canada, and one in Wyoming.) Why are we seeing fewer Bald Eagle fatalities?

The location of projects and reporting requirements are two possible sources of bias, but it may be that Bald Eagles are less at risk than Golden Eagles because of differences in behavior. In 2006, we began to look at an area with high Bald Eagle use, Pillar Mountain in Southwest Alaska, where the Kodiak Electric Association proposed to site a wind energy project.

Pillar Mountain is a 360-m tall ridge that overlooks Kodiak, Alaska. The vegetation on the top of Pillar Mountain is tundra, with patches of Sitka spruce, willow, and alder shrub at lower elevations. The ridge is oriented northeast to southwest, and is very steep on the southeast side. Topography and wind patterns create good soaring opportunities for eagles at Pillar Mountain. Bald Eagles are common throughout the year at Kodiak, and are reported by locals to roost on the steep southern face of Pillar Mountain during the winter. This wind project is not located in breeding habitat, and the food is down below the project site in Chiniak Bay. Tall structures, including communications towers, have been present on top of Pillar Mountain since World War II, so eagles in this area are accustomed to having tall structures on the landscape.

Initial pre-construction surveys in 2006 (funded by Kodiak Electric Association [KEA]) showed that this is a high-use site for Bald Eagles during the spring, making it a good site and season to study potential effects of wind turbines. We did surveys at the other seasons, but use was very low outside of spring.

## **Methodology**

Standardized avian point count surveys were conducted for 30 minutes during the spring (March 15 through the end of May) in 2007 (pre-construction) and 2010 (post-construction) by the same observer.

Thirty-five surveys were conducted during 2007 and 33 surveys in 2010. For each Bald Eagle observation, which could be an individual or a group, we recorded the number of birds observed, activity, flight direction, whether birds flew across the ridge, and the range of flight heights in relation to the ridgetop where turbines were proposed. We also mapped flight paths.

For both the 2007 and 2010 surveys, for all birds and then only those birds observed flying across the ridge, we calculated the number of birds observed per 30 minutes, number of observations per 30 minutes, mean group size, proportion of all birds observed flying across the ridge, and proportion of birds flying within the elevation zone swept by the turbine rotors.

## **Preliminary findings**

Slide #19 shows pre-construction flight paths mapped in white and post-construction flight paths mapped in blue. (Turbine locations are indicated in green, and an orange box defines the turbine area.) There is no difference in mean use from 2007 to 2010. However, the 15% percent of birds that were crossing the ridge between turbine locations (within the orange box) prior to construction dropped to zero once the turbines were built. Birds continued to cross the ridge in other places around the turbines.

No incidental fatalities have been recorded since construction.

Kodiak plans to put up three more turbines to the west of the existing turbines, down the ridge.

## **Questions & Discussion**

***Did the FWS think that take of Bald Eagles was likely to occur from operation of three turbines? If so, how was Bald and Golden Eagle protection act take prohibition addressed? If take was determined to be unlikely, how was this determination reached?***

Sharp: In 2006 KEA received a letter from the FWS expressing concern about the possibility of fatalities; this letter was the stimulus for this study. KEA is a utility and has had an Avian Protection Plan in place for many years.

***When observers counted the number of eagles to determine mean use – did they record the amount of time spent in the area? Were there any changes in the amount of time spent in the area by individual birds?***

Sharp: They did not record amount of time eagles spent in the area – just observed and mapped the flight paths.

***What was the closest Bald Eagle observation to a turbine? Did this differ from the closest approach to a met tower?***

Sharp: We did not record an estimate of the distance at closest approach to turbines or the met towers during the field surveys, so we can't answer that question. Measuring distances on the flight path map would not give you accurate information because the flight paths were visually estimated (they were not

radar flight paths). In addition, the flight height of the birds at closest approach to the turbines was not specifically recorded. We recorded the high and low altitude in relation to the ridgetop where the turbines were located, and birds with the same mapped flight paths that flew below the ridgetop would be farther from the turbines than those flying at the same level as the turbines. Ravens were observed to perch on the met tower, but eagles did not.

***Was the operational status of each turbine noted during surveys?***

Sharp: No.

***What is the megawatt rating of the three wind turbines on Pillar Mountain? What is the hub height of these turbines?***

Sharp: These are 1.5 MW turbines with a hub height of 80 meters.

***Did you do a nest survey? If so, how far away was the nearest eagle nest from the turbines?***

Sharp: We did not do a nest survey.

***Given that eagles are extensively using the area to the left/east of the three turbines, can you make recommendations to the developer for a “best” place to put turbines?***

Sharp: I would need to think about that – I would want to look at control data.

***What are the implications for low overall Bald Eagle impacts?***

Sharp: Wind is like real estate – it’s all about location! If wind farms start getting built in heavily-used areas, we’ll likely start seeing more fatalities. It depends what birds are doing on that landscape. In addition, it would depend on how many turbines were present. It’s pretty easy for an eagle to avoid three turbines that aren’t near a nest or important feeding area or roost. It would be a different situation if there were 50 turbines surrounding a nest, foraging area, or roost; or if there were turbine strings in between foraging and roosting areas, for example.

***What is Fisher’s exact test?***

Sharp: A Fisher’s exact test is a type of significance test for contingency tables where the expected value of any cell is below 5. For larger samples, a chi-square test can be used, but because of the small sample for some categories analyzed, a Fisher’s exact test had to be used. The Fisher’s exact test was used to determine if the proportion of birds flying between turbine locations differed between 2007 and 2010.

***Was Bald Eagle behavior altered during construction activity on Pillar Mountain?***

Sharp: We can’t say for sure because we did not conduct surveys during construction. I asked KEA staff and their impression was that the eagles avoided the site during turbine construction in the summer of 2009.

***Were setbacks from the slope considered or incorporated into the design and construction of the wind farm (e.g., 500 m from the edge)?***

Sharp: Setbacks were not possible given the steep terrain on both sides of this mountain.

## ***A Case Study of the Interaction between Landscape Configuration and Wind Farm Visitation by Golden Eagles***

[Junior Tremblay](#), Ministère des Ressources naturelles et de la Faune (MRNF)

(Co-authors : Charles Maisonneuve, MRNF, Québec; Todd Katzner, West Virginia University; Tricia Miller and Michael Lanzone, Carnegie Museum of Natural History; David Brandes, Lafayette College)

[Link to Presentation](#)

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**Research objectives:** Determine how landscape level habitat structure affects space use by Golden Eagles near wind energy facilities.

**Hypothesis:** A higher proportion of open habitats near wind energy facilities close to Golden Eagle nests will increase use by Golden Eagles of such areas surrounding the wind energy facilities.

**Key terms:** Golden Eagle, habitat configuration, Quebec, satellite telemetry

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Quebec plans to increase its production from about 500 MW today to 2000 MW in 2012 and to 4000 MW by 2015. Some wildlife species are more vulnerable than others to blade-strike mortality, and Golden Eagles (*Aquila chrysaetos*) are known to be one of those. Not all wind energy facilities present the same risk of mortality; turbine configuration and site particularities are two major parameters to take into account when evaluating such risks.

This study aims to determine how habitat configuration affects space use of breeding Golden Eagles, with a particular focus on areas adjacent to wind energy facilities. We hypothesized that a higher amount of open habitats in the vicinity of wind energy facilities will increase use by Golden Eagles of the wind energy facility area.

Golden Eagle breeding areas are relatively rare in the Northeast, and mostly found in Quebec, where there are 82 known nesting sites. Our study area focuses on the Gaspé Peninsula. Currently there are two operational project areas on Gaspé, but of the 1,900 turbines planned to come on line by 2015, two-thirds of them are to be located on this peninsula (slide #4 – existing facilities in green, planned facilities in yellow).

### ***Methods***

We outfitted Peregrine falcons, Golden and Bald Eagles with Argos/GPS solar transmitters to delineate home ranges and determine possible overlap with wind energy project areas. We looked mainly within 20 km of nests, but in the case of Golden Eagles, we also looked at nests further away. Eagles were captured using live crows (breeding season) or deer carcasses (fall) and bow-nets.

### ***Preliminary findings***

Slides #9-11 map Golden Eagle home ranges for three nesting sites. Habitat is mapped as either forest (> 3m), forest cut areas (cuts < 15 years old), burn areas, and barren lands similar to tundra. For the first territory (Mt. Ernest Laforce), the eagle's home range does not overlap with turbine sites. At Lac

Matane, there is no active wind facility in the vicinity. Mount Pico has huge home range, extending as far as 43.1 km from the nest. There is very little open habitat within this territory, and the home range completely overlaps with a wind facility 15 km from the nest.

Slide #12 maps eagle movements within the Carleton wind energy facility. Activity is concentrated within the northeastern part of the project area. One Golden Eagle passed 12 hours on the ground within 100 m of a turbine, but this was when researchers were doing carcass removal testing.

Preliminary results show that nests established in areas with high availability of open habitats had smaller home ranges and individuals were less susceptible to using open habitats surrounding wind energy facilities. Where open habitats near Golden Eagle nests were less available, openings created near wind energy facilities offer new hunting areas, increasing the use of the wind energy facility by eagles, and thus increasing potential risk of blade-strike mortality.

### ***Implications***

Developers aiming to establish wind energy facility projects in forested mountainous areas, as is the case for many projects in Eastern North America, should consider that creating openings within a forested habitat may increase collision risk for Golden Eagles.

### ***Preliminary conclusions***

- Eagles nesting in areas with **high availability** of nearby **open habitats** have **smaller home ranges** and are less prone to using open habitats surrounding wind facilities.
- Eagles nesting in areas with **low availability** of nearby **open habitats** have **greater home ranges**, and may be attracted to openings created near wind facilities which offer increased hunting areas; they may thus have greater risk of collision with turbines.
- Home range sizes justify our priority to monitor nests within 20 km of wind facilities.
- Efforts must be made to avoid location of wind facilities near Golden Eagle nesting sites. When this cannot be avoided, we recommend:
  - Minimizing forest cuts around wind turbines
  - Examining the possibility of increasing open habitats near nesting sites
  - Being aware of possible effects of carcass persistence tests in attracting raptors to the turbines.

### ***Next steps***

We plan to do another trapping session so that we can increase our sample size, and to continue field observations within the Carleton wind energy facility to evaluate movement behavior.

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## Questions & Discussion

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***How did Golden Eagle use change with increasing distance from nests? Was there a linear or non-linear decline in use? What were 25/50/75% distances from nests for proportion of use?***

Tremblay: I don't know. But eagles were more active, and spent more time, nearer to nest than farther away. We hope to have more information – home range scale analysis and fine-scale analysis – next time.

***Given that the home ranges of your 3 eagles ranged from 500-2000 km<sup>2</sup> – how did you arrive at your suggestion of siting wind power more than 20 km from Golden Eagle nests?***

Tremblay: This distance was fixed before our study, but our study suggests it might be farther than that.

***What is the prey base for eagles in Quebec?***

Tremblay: We are doing research to better understand that. From what we can tell so far, they are eating birds, hare and marmots.

***What was your success rate for capturing adult Golden Eagles using a bow-net with live crows?***

Tremblay: Live crows are the best bait. It is much harder to capture eagles with deer carcasses.

***What distance do you recommend for wind turbine siting near Golden Eagle nests – i.e., minimum distance?***

Tremblay: It is hard to give an adequate value; it all depends on the amount and quality of habitat available in landscape.

***You spoke about eagles possibly being attracted by carcass placement. Did they do any carcass changes to reduce attracting Golden Eagles?***

Tremblay: The developer stopped the carcass persistence test and used the evaluation from 2009.

## ***Response of Raptors to a Wisconsin Wind Energy Facility***<sup>\*</sup>

[David Drake](#), University of Wisconsin – Madison

(Co-authors: Julia C. Garvin, Christopher S. Jennelle, Steven M. Grodsky, Department of Forest and Wildlife Ecology, Madison, Wisconsin)

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**Research objectives:** Determine: 1) whether raptors are being displaced from within the wind energy facility, and if so, which species are most vulnerable; 2) the proportion of raptors displaying avoidance behavior (i.e. changes in flight path to avoid a turbine or its blades); 3) the relative risk of collision of each raptor species, and of all raptors as a group; and, 4) potential correlations with observed mortality and estimated avoidance rates.

**Hypotheses:** We expected to see: 1) no evidence of displacement from wind energy facility project areas; 2) species-specific differences in both avoidance behavior and collision risk; and, 3) few raptor mortalities since avoidance rates are likely to be high.

**Key terms:** behavior, displacement, raptors, Red-tailed Hawk, Wisconsin

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<sup>\*</sup> Slide presentation not available as part of this Proceedings.

Wisconsin currently has ten wind energy facilities totaling 449 MW. Another 22 wind facilities totaling 1500 MW are in the planning stages, as part of the state's strategy to achieve 25% renewable energy by 2025.

In the context of this substantial expansion of wind energy, the goal of this research was to evaluate potential impacts of a 129-MW wind energy facility in southeast Wisconsin on the abundance, richness, and behavior of raptors within the project area. Raptors as a group are more susceptible to wind turbine collisions, with a greater potential for population impacts because they are long-lived birds with a low population density and low reproductive output.

### ***Study overview***

Our study area consists of and 13,100-ha project area with 86 GE 1.5 MW turbines, located in Fond du Lac and Dodge Counties, just east of the Horicon National Wildlife Refuge. The wind project itself is situated in an agricultural area (97% cropland, 2% woodland). The turbines are 118 m tall, with rotor planes that are 77 m in diameter. It is part of a larger avian use study (see Oct. 19 report from Steve Grodsky, p.18).

Horicon is the largest cattail marsh in the U.S. (12,950 ha), a wetland of international importance, and a state and globally important bird area supporting approximately 300 species of birds. Although the wind project itself is located on a less ecologically sensitive agricultural area, there was concern about the impact of the wind energy facility on the marsh.

From April 2005 to March 2006, raptor surveys were conducted between 9 am and 3 pm, for one hour at each of 12 stations located throughout the project area. Similar surveys were conducted June to August, 2008, and from April to August 2009. Eight reference stations were added in the summer of 2009.

Survey data included:

- Species
- Number of individuals/groups
- Behavior
- Flight height (with reference to the rotor swept zone between 41 and 118 m agl)
- Response approaching turbines (avoidance, no-response, high-risk behavior – i.e., flying through the rotor plan or circling the turbine)

We also looked at Kerlinger's data from the same time of year for 2005-06.

Other data recorded included habitat information (as stated, this is a human-dominated landscape), time of day, and weather – i.e., percent cloud cover, precipitation, and wind speed.

### ***Statistical analysis***

We looked at raptor abundance and behavior analysis relative to both fixed variables (year, time of day, weather, habitat) and random variables (survey station, visit). We used a Madders and Whitfield avoidance rate<sup>3</sup> and Huso's mortality estimator (2010) to correct for searcher efficiency and scavenger removal bias.

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<sup>3</sup> Madders, M. & Whitfield, D.P. (2006) Upland raptors and the assessment of wind farm impacts.

## **Results**

Species abundance. Turkey Vultures (1,248) were the most abundant raptor species observed in all years, followed by Red-tailed Hawks (780), Northern Harrier (107), American Kestrel (43) and Cooper's Hawk (30). The four species top-ranked in terms of abundance remained consistent pre- and post-construction.

Overall, there was a 47% reduction in raptor abundance pre- to post-construction. We observed fewer raptors during rain periods. When we began making observations at reference stations in 2009, we found 61% higher abundance at reference stations, but no difference in abundance based on distance to marsh or to turbines.

Relative abundance (number of birds per hour per species) was marginally lower post-construction. For most raptor species, relative abundance dips from 2005 to 2008, but begins to pick up again in 2009. Turkey Vulture relative abundance lagged, dropping off in 2009 for a -82.5% overall decrease from 2005-2009. Other species that showed significant decreases in relative abundance were Northern Harriers (-61.8%) and Red-tailed Hawks (-52.4%).

Species diversity. Diversity was measured as number of species observed per survey per station. We saw 33% less diversity post-construction, but observed no difference in 2009 between reference stations outside the wind turbine boundary and survey stations inside the project area. Diversity increased with grassland habitat, but again we saw no effect of proximity to marsh or turbines.

Behavior – flight height. Flight height patterns were species-specific, varying with station, time-of-day, weather, and observer. These patterns did not change pre- to post-construction, with most birds flying above the rotor swept zone.

Risk of collision. Sixty-three percent of raptors flew within the turbine arrays, and 49% within the rotor zone (41-118 m agl), but only 11% were observed to fly within the rotor plane, or within 100m of turbines at rotor zone level. Of these, 32 were observed to show avoidance behaviors, while 54 exhibited high-risk flight patterns – particularly Turkey Vultures and Red-tailed Hawks.

Mortality. Very few carcasses were found – 2 Red-tailed Hawks, 3 incidentals. Mortality data were provided by Steve Grodsky (see p. 18), and are similar to findings at other U.S. wind energy facilities.

## **Conclusions**

The collision avoidance rate was 100% with the exception of Red-tailed Hawks (98%). This suggests that, despite what appeared to be some high-risk behaviors, there is a relatively low risk of collision.

We are confident that there was some displacement of raptors, both in terms of abundance and diversity. Abundance was higher outside wind energy facility, and there was no change in bird abundance surveys in other parts of Wisconsin.

The implication for management is that we need to look at cumulative impacts of displacement regionally and beyond. We want to make some regional comparisons with data from nearby wind

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energy facilities, estimate cumulative impacts and do some population viability analysis. This will help us to fine-tune state guidelines for future wind energy development.

## Questions & Discussion

***Did age appear to increase susceptibility for those raptors flying through the rotor plane?***

Drake: We did not record age data.

***What was the most common behavior recorded when a raptor was performing an at-risk flight through the rotor zone?***

Drake: Either just flying through it or they were hunting.

***Does the finding that cleared area around turbine increases hunting in the area imply that clearing or mowing to facilitate post-construction searches increases risks to raptors?***

Drake: I don't really have an answer to that question. We searched linear (5-m wide) strips. We also searched areas around turbines that have been cleared.

***Are there any indications that other raptors that commonly fly near human built structures may also be at risk (besides Red-tailed Hawks and Turkey Vultures)?***

Drake: It's an interesting question. We're doing another paper on all avian use at that site. Abundance went down for raptors at this site, but not for avian use overall. The fact that turbines are dynamic structures may make a difference.

***Why did you choose the months you did for the study? Many raptor studies include the fall migration – why didn't you? What impact do you think timing has on the conclusions of the study?***

Drake: Because of a pre-construction study design that we did not develop or conduct, we were restricted to conducting our raptor study post-construction during the same months as the pre-construction study in order to allow for direct comparison pre- and post-construction.

***Was the time of observation randomized per station?***

Drake: Yes.

***Do you know how many nests were in the vicinity of your project, and if so, would a buffer setback have helped?***

Drake: We did not know the number of nests in the vicinity of our project area.

***Is there any concern with waterfowl (geese, ducks) or Sandhill Cranes in proximity to Horicon? Was the number of raptor nests recorded?***

Drake: The number of raptor nests was not recorded. We looked specifically at impacts to geese (and other waterfowl) and Sandhill Cranes in this study as well as a complementary mortality study. No waterfowl or Sandhill Cranes were negatively affected.

## Session 4: Modeling

**Moderator: Doug Johnson, USGS Northern Prairie Wildlife Research Center**

Can we start using models to help us predict accurately, and to help wind developers know where to site and what they need to do when they are siting? There are three things we need to know about models:

1. A model is an abstraction of reality.
2. Models vary; which model is better depends on your purpose.
  - Consider two models of mallards: a mathematical model of mallard nesting success and a wooden duck decoy are both abstractions. The first model is good for understanding population dynamics. Wooden mallard models are better for attracting birds for hunters.
  - Consider two maps of North Dakota. One is a road map, the other a wind resource map – again, different models for different purposes. Each model abstracts only the necessary pieces of reality, depending on the user’s objectives.
3. Models incorporate knowledge and assumptions, allowing you to input data and output predictions.
  - The more knowledge you have, the more certain the predictions; the more assumptions you have to make, the less certain the predictions.

Some comments about models:

- “Models are a work of fiction.”
- “Models, like hypotheses, cannot be proven correct.”
- **“All models are wrong ... but some models are useful.”** (George E. P. Box) This actually is the fourth thing you need to know about models.

There are three general categories of modeling purposes (not mutually exclusive):

1. Predictive – you know the input and have a model, so want to predict output.
2. Explanatory – you see a system and its inputs and outputs, and you want to understand what is happening (also called mechanistic, functional, or causal).
3. Control – model tells you what inputs you need to yield the desired output (useful, e.g., in chemical manufacturing).

Correlational versus mechanistic – example: Fifteen elementary students were tested in mathematics, and the data show a positive correlation between test scores and the weights of the children. Does this mean that overweight children do better in math? Probably not. Weight is also correlated with age; on average, the fifth graders weigh more than the second graders. And indeed, age shows an even better correlation with test scores. Does this mean that children get better at math just by virtue of getting older? Probably not. Years of instruction also is positively correlated with performance. This is more of a mechanistic model; we have more comfort with the idea that children get better at math by receiving instruction, not by over-eating or simply aging. Yet note that the correlation is not as tight for years of instruction as it is for some of the other factors – i.e., from a model-fitting perspective, there are other models that do better than the mechanistic one.

Mallard nest success model – example: Mallards can nest several times during the year if they fail at their earlier attempts. If we plot the success rate of individual nests against an individual hen’s success

over the whole breeding season to account for re-nesting, we see at first a linear relationship: hen success = 0.3 + 1.54 \* nest success. But if we manage the habitat so that nest success increases to around 70%, hen success goes above 100%, which is an impossibility. With correlational models, such as this one, there is a danger of extrapolating beyond the range of your data. In this case, a non-linear model is required – a model that is mechanistic rather than descriptive. The early part of the curve looks linear, but with this mechanistic model, when nest success is 70%, hen success reaches only 76%, not 110%.

*Validation versus evaluation* – Finally, let's consider the concept of model "validation." Definitions of validation in the modeling literature are often circular or subjective ("do we have faith in the validity of the results?"). The concept of "usefulness" – does the model contribute to better decision? – begins to get at a meaningful definition, so I would suggest replacing the word "validation" with "evaluation":

A model has **value** if it provides better insight or predictions or understanding or control than would be available without the model (Johnson 2001).

Corollaries:

- Evaluation is assessing the credibility of the model for its intended applications.
- Evaluation is not absolute; one model may have more value than another for a certain application, but they could both have value.
- Evaluation is specific to the purpose of the model; it is not intrinsic to the model.

## ***A Habitat-based Wind-Wildlife Risk Tool with Application to the Upper Great Plains Region***

[Greg Forcey](#), Pandion Systems, Inc.

(Co-authors: Caleb Gordon, Joanna Burger and Larry Niles, Pandion Systems)

[Link to Presentation](#)

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**Research objectives:** To model collision probability of Horned Larks across the central United States using both indexes of abundance, habitat, and exposure.

**Key words:** hierarchical models; spatial models; Horned Lark; count data; collision models

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Avian collision mortality with wind turbines has been a widely studied topic through both pre- and post-construction monitoring studies in the United States. Most of these studies have occurred at the scale of the individual wind power facility and have not examined large-scale mortality effects and siting options at the state level or beyond. We modeled collision mortality of Horned Larks as a function of bird abundance, habitat, and estimated exposure conditions to wind turbines in the central United States. This work is being done for the Department of Energy with the goal of developing spatial collision models based on biological and environmental variables. This will allow us to generate maps of relative predicted collision mortality for each species.

Slide #3 shows the geographic area we chose to model. This is a large area of the central United States characterized by prairie landscapes – central mixed grass, short grass, pothole, and badlands – and by fair to excellent wind resources as well as bird and bat migratory corridors.

Separate models were constructed for each season given the temporal variation in abundance and exposure. We estimated bird abundance by modeling bird abundance from the North American Breeding Bird Survey and Christmas Bird Count as a function of land use. Mathematical land use models were mapped back into the landscape in a GIS environment to create a grid of predicted abundance across the study region. Because we did not have bird abundance data to model during migratory seasons, we estimated occurrence during migration by mapping migratory habitat based on known habitat preferences from the literature.

Exposure was modeled using data on topography, weather, and behavior; exposure models were specific to each season given the large differences in behavior and weather across seasons.

Abundance (winter and summer), habitat (migration), and exposure (winter, summer, and migration) models were combined to form a cumulative measure of collision probability across all seasons.

We focused on six bird species from a variety of taxa, including endangered species, as well as three bat species: Red-eyed Vireo, Mallard, American Avocet, Golden Eagle, Whooping Crane, red bat, silver-haired bat, and hoary bat. Because we were looking at large geographic areas, we had to rely on existing data. For birds, this included: the North American Breeding Bird Survey, Christmas Bird Counts, eBird Data - Quality Controlled (for migration), and also FWS data on Whooping Cranes. For bats, we relied on known habitat associations from the literature and NatureServe range maps.

Conceptually, the approach is to develop a hierarchical spatial model to predict abundance, factor in exposure data, and then weight it according to how much time species spend in the habitat during each season. (See slide #8.)

Model validation/evaluation occurs at two levels. The first is comparing predictions with observed results, using the 20% of data withheld from the data set used to build the model. The second is to compare the predictions with other mapped models.

Slide #10 shows the general approach to the bat model; note that fall and spring are weighted separately. Bat models are based on known habitat preferences, including the following defined habitat features that influence bat occurrence: percent forest; forest edge density; forest stand age; percent open water; distance to water; and riparian flyways.

We conducted a moving window analysis using 2- and 10-km moving window sizes, to quantify land use variables. (This was a very time-intensive effort, taking a week per variable to compute!) See slide #13 for an example. In the map at left, each color represents a different land use variable. In the map at right, the colors represent the percentage of open water. Each moving window analysis quantifies the landscape in terms of a particular variable; these maps must then be aggregated.

For both birds and bats, the model also incorporates behavior, weather, and topography variables:

- Behavior - determine if species has behaviors that increase exposure (e.g., aerial foraging, courtship, nocturnal migration)

- Weather - derive grids of weather variables thought to increase exposure (e.g., fog, rain, wind, temperature)
- Topography – identify areas of high slopes

### **Applications**

Our research has application to regional scale siting of wind power facilities, making comparisons of collision probabilities among sites, and developing site-specific priorities for additional research. This modeling approach can also be expanded to other species and geographic regions in the United States to aid in siting wind power facilities.

## **Questions & Discussion**

### ***Are there examples of models like this being used in planning siting or operation?***

Forcey: We have developed a Bald Eagle model for a client to look at the potential for collisions at a site in Maine.

### ***What about looking at the population level?***

Forcey: No, this tool is site-specific.

### ***Do we have enough data for bat or other population models?***

Arnold: What we learned ten years ago was that we didn't have enough information about the nature of what the population was.

Forcey: For land birds, the best population estimates are Partners in Flight estimates – that's the best available data. [[http://www.rmbo.org/pif\\_db/laped/default.aspx](http://www.rmbo.org/pif_db/laped/default.aspx)]

### ***You mentioned using modeling in siting a wind facility. How is model uncertainty viewed in terms of the agency and developer discussion?***

Forcey: Models are tools for answering questions and making decisions. In this case the model is one of several tools that will be used to make decisions in that particular project.

### ***Can you discuss the results of the models? What areas had the greatest collision risk?***

Forcey: These models are in process and are not yet complete.

### ***What was the source of the bat data?***

Forcey: Large-scale datasets on bat distributions are not available, so we are predicting bat occurrence based on known habitat associations from the literature.

### ***Where did you get forest stand age data for your model?***

Forcey: We developed our own "in house" forest age stand data based on available data on forest canopy height and forest biomass data. These datasets are available from [landfire.gov](http://landfire.gov)

***How do you estimate and represent prediction uncertainty?***

Forcey: We will perform model validation using freely available independent datasets within the study region. This validation will reveal how the models will perform within the range of values in the dataset.

***Modeling Wind-industry Effects on Wildlife: Framing Concepts for Assessing Population Impacts***

[Joseph Grzybowski](#), University of Central Oklahoma

(Co-authors: Craig Pease, Vermont Law School; Gary Schnell, University of Oklahoma)

[Link to Presentation](#)

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**Research objectives:** Develop perceptions for the value of modeling population-level effects to wildlife from wind energy facilities, and assess the needs and opportunities.

**Key terms:** competing risks, displacement, modeling, mortality, population dynamics

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Population modeling was identified as a priority in 1995, but it may have fallen out of the picture. There are various ways of modeling; most people here are using analytical algorithms. There are two general population-level impacts of wind-energy development on wildlife: landscape-level displacement and direct mortality. This presentation will focus on dimensions of mortality to migratory bats, as an example.

The largest mortality impacts of wind energy development have been on hoary and red bats, silver-haired bats, and Mexican free-tailed bats (Slide #6). These are longer-distance migrants with low reproductive potential, which raises questions and concerns about population-level impacts.

Population models should incorporate three general parameters: one depicting population status and the others depicting measures of births and deaths. The simplest form of a model would be to insert counts of individuals, but we cannot obtain such counts. As alternatives, we frame models in the dynamic of change, setting some boundaries on the population under consideration and estimating per capita births and deaths, or we can use some depiction of fundamental population processes (age structure, assumptions on annual mortality/survival) to establish the population status. For example, if an individual has an 80% chance of annual survival, at least 20% of the population need to be yearlings for the population to be viable – i.e., stable or increasing.

For bats, we do not know much about population parameters. The wind industry has focused on measuring mortality and developing and testing measures to reduce it on a per-turbine basis. But there are issues of scale. Migratory bats that are killed by turbines are parts of populations that cover large areas, which means we don't know whether the impact of those collisions is significant or insignificant.

### ***Implications for research***

What to do? This condition of measuring mortality at turbine sites presents significant opportunities to centralize and organize potential information, either physically (e.g., possibly creating a central repository for collectively organizing carcasses) or electronically. This could allow us to perform analyses identifying the spatial scale of impacted populations and to develop or refine techniques for assessing the regional origin of bat fatalities.

### ***Caveats***

The interplay of variables is not always intrinsically intuitive. This underscores the value of modeling. Some summary statistics or an intuitively appealing parameter can be misleading. For example, nest success has been an appealing parameter for measuring reproductive success in birds, but misleading on population dynamics. Consider, for example, that a female with three nesting attempts of which only one is successful (66% nest mortality) produces as many young as a female with one successful nest (0% nest mortality). Thus seasonal fecundity, not nest success, is the population parameter of interest (see slide #23).

Competing risks: In addition, it is important to keep in mind that an individual animal can only die once. If a population is subjected to two risks, each 40%, eliminating one does not decrease mortality by 40%, rather only 13%. And, we have information about season-specific mortality for bats; that can be placed into the context of competing risks.

### ***Implications for research***

Population modeling is very useful for assessing and interpreting impacts. Even with limited empirical data, population models help us to focus on the most useful data needs, and on the most worthwhile directions or meaningful future research.

## **Questions & Discussion**

### ***How would data be “organized and centralized” so that it could be shared yet remain secure?***

Grzybowski: Relative to mortality issues, and particularly for the bat species most affected: There are two general approaches. One is to centralize specimens so that they might be used to establish samples for assessing various origin and demographic parameters. The second is to centralize the information on these carcasses so that individuals wanting to address specific questions can assess the available resources.

## ***Estimating Population-level Risks for Wildlife from a Landscape Perspective: A Framework for Assessments at Wind Energy Facilities***

[J. Robert Pastorok](#), Integral Consulting, Inc.

(Co-authors: Matthew Behum and Damian Preziosi, Integral Consulting, Inc.)

[Link to Presentation](#)

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**Research objectives:** Present a risk assessment modeling framework integrating habitat analysis from a landscape perspective, modeling to predict wildlife mortality from turbine encounters and population-level risk assessment/management. Improve the risk assessment process for predicting risks to wildlife associated with wind energy facilities.

**Key terms:** encounter, habitat, landscape, population modeling, risk

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Estimating risks to wildlife populations from encounters of birds and bats with wind turbines is important in several phases of wind power development, including evaluating the potential location and design of a facility, operational monitoring, and impact mitigation. Yet methods for predicting encounters and evaluating relative risks of alternative plans for wind farm planning/management are still in the early stages of development. We present here a risk assessment framework that integrates wildlife habitat analysis from a landscape perspective, models turbine encounters to predict bird and bat mortality, and helps us think about how to analyze and mitigate population-level risk.

### ***Why population modeling?***

In the context of regulations for protection of special status species, individual take can be significant. Apart from that, however, mortality estimates are practically meaningless because they cannot (by themselves) be used to assess population-level effects. Population modeling is a useful tool for interpreting potential impacts of wind energy facilities, including mortality due to turbine strikes, displacement of individuals due to habitat modification, or attraction of species associated with newly created habitats. Such models integrate effects on growth, survivorship, reproduction, and movements of individuals to estimate metrics such as density of individuals, total abundance, age/stage structure, and measures of spatial-temporal distribution. By focusing on population-level impacts, we are able to:

- Achieve ecological relevance in our assessment while using tractable models
- Integrate multiple stressors and assess cumulative effects
- Establish a basis for endangered species evaluations (ESA)

Population modeling is also amenable to spatially-explicit assessments using GIS and individual-based models.

### ***Modeling issues***

In modeling, the selection of endpoints and risk expressions is critical. How population models are used to extrapolate from lower-level effects (organism-level measures such as survivorship rate and fecundity) to relevant risk metrics (probability of population decline, extinction, fragmentation, and genetic loss) may vary depending on the context. Thus it is important to formulate the problem carefully, and decide what you really need to assess.

The assessment population is usually smaller than the biological population. The scale of analysis should be decided by stakeholders during problem formulation – whether it be an evaluation of alternative sites during the planning phase for a wind power facility, a risk assessment for wildlife interaction with wind turbines, or other analyses. The spatial scale may range from a local project to a watershed or regional assessment, to a “whole population” (national or international) scale.

### ***Key elements of framework***

There are three key elements of the proposed risk assessment framework:

1. Wildlife habitat analysis from a landscape perspective
2. Turbine encounter modeling to predict bird and bat mortality
3. Population-level risk analysis/mitigation

Slide #6 illustrates the types of data that are input into these three model elements, with the model outputs shown on the right. How do you communicate the risk estimates so that discussion is productive and clear? The posters at this meeting show real progress has been made in this area, which is critical if research and modeling are to contribute to good policy and project-specific decision-making.

### ***Potential applications***

Population modeling is a useful tool for several phases of development and operation of wind energy facilities at various spatial-temporal scales, not just for cumulative impact assessments at the scale of the biological species population. As an example of one element of the proposed risk assessment framework, Slides #9 & 10 illustrate a landscape connectivity model that is essentially the converse of habitat fragmentation analysis. In this case, four factors and a scoring system are used to estimate “patch value” in the context of an entire landscape. In effect, this model looks at how eliminating or restoring a patch affects the value of not only that part of the landscape, but also of other patches in the matrix.

Determination of habitat patch value related to connectivity (or conversely, landscape fragmentation) is important for habitat analysis during development and evaluation of alternative plans, including:

- selection of sites for wind energy facilities
- pre-and post-construction monitoring
- selection of habitat mitigation sites

In a risk analysis, habitat patch value is an input to the turbine encounter model (slide #7). The evaluation of the ecological significance of risks should consider landscape distribution of habitat value relative to turbine locations. During post-construction monitoring, the landscape model allows us to interpret mortality estimates relative to habitat spatial distribution.

## **Questions & Discussion**

***In your slides, demographic responses didn't include emigration and immigration. How do you suggest handling these demographic factors?***

Pastorok: For many population analyses, especially for planning of wind development projects, one would conduct a relative risk analysis, and emigration and immigration can be ignored since they would

factor out of the analysis anyway. The exception is the case of displacement of species due to habitat modification or attraction of other species by newly created habitat. In that case, one has to quantify the relationship between a species and habitat characteristics, as in a resource selection function or similar model. Net movement into or out of an area could be addressed by comparing habitat before and after wind site development.

For a different evaluation, for example using a population model to interpret the significance of mortality due to turbine strikes, whether immigration and emigration are taken into account depends on whether a meta-population model is used. If so, then one has to quantify movement between subpopulations. If this is unknown, then it may be addressed by sensitivity analysis to explore what level of movement among patches would be important. In the case of a spatially aggregated model, one wants to know what the risk to the assessment population is in the absence of emigration and immigration – particularly the latter, as a precautionary approach would not want to let immigration balance any loss of individuals due to turbine strikes (i.e., allowing creation of a “habitat sink” in the landscape).

***Suitable framework and scale for modeling and managing risk to migratory bats at wind projects***

[Trevor Peterson](#), Stantec Consulting, Inc.

[Link to Presentation](#)

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**Research objectives:** Explore whether or not traditional site-specific screening for rare species is suitable as a long-term method for minimizing potential impacts to at-risk bird and bat species at wind projects.

**Key terms:** risk assessment, regional model, bat migration, cumulative impacts

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The regional cumulative impacts to migratory species should be considered in the evaluation of wind projects, as these species tend to be more prone to collisions. Whereas the current permitting process in place for wind projects in most states focuses on site-specific information regarding migratory species, a regional perspective is essential for understanding, managing, and mitigating impacts to long-distance migratory species, which may be more at risk of long-term cumulative impacts from wind projects than rare species less prone to collision. Methodology for assessing impacts to bird and bat species as a result of wind projects should be broadened to better assess impacts to migratory species on a large-scale, regional perspective.

This presentation applies technical aspects of modeling to three central questions, with a focus on the third question:

1. Where to develop wind energy facilities (site-specific)?
2. What are the impacts (regional and cumulative)?
3. How can these impacts be managed?

There are three species of long-distance migratory tree bats in eastern North America: the eastern red bat, hoary bat, and silver-haired bat. It is difficult to come up with population estimates for these animals, because they do not form countable colonies, and migrate on a large scale. None of these three species are currently listed, but they do comprise the majority of fatalities, and they are slow-reproducing species, which gives rise to concerns about the possible population impacts of individual fatalities.

Avoiding problematic sites is easy for some species, but less feasible for these bat species, because little is known about their ranges and migration routes. We have a broad idea, but nothing specific enough for siting purposes. The more relevant question, then, may be how best to manage site operation so as to minimize impacts.

There are several challenges to developing a regional model. Uncertainty is a problem, but it is also the reason for using models; models give us a structure for making decisions in the absence of certainty. Because we are still collecting data, any model we develop needs to be flexible to accommodate information as it is collected.

### ***Industry parallels***

Other industries offer some useful regulatory parallels. By-catch is a persistent problem for fisheries, just as bat mortality is an incidental cost of the wind industry. Fisheries manage the by-catch problem by adjusting gill net size; the parallel for wind turbine operations might be cut-in speed, which has the advantage of being a flexible tool.

Likewise, a harvest model – used in other industries – is potentially useful here. Coming up with industry-wide mortality patterns would enable us to extrapolate a “predicted take level” that can be considered on a population level. The objective would be to find an acceptable (equilibrium) take level.

How would we implement a model like this? Migratory routes cross boundaries, so no single regulatory framework encompasses the whole population landscape. Can the industry self-manage? There is real opportunity for innovation in this area, and this is a good forum for that discussion.

## **Modeling Discussion**

For this session, Bill Kendall and Tony Starfield were asked to discuss broader questions about the use of and approach to modeling rather than focus on specific details from the presentations.

### **Bill Kendall (U.S. Geological Survey, Colorado Cooperative Fish & Wildlife Research Unit)**

Modeling has to be put in a decision context – whether it’s the wind industry or a state agency or the federal government, somebody is using modeling to make decisions. Indeed, in a decision-making context, modeling is inherent, because any decision you have to make requires a prediction of what the consequences of that decision will be. Consider the elements of Adaptive Resource Management, or any informed management process. Implicitly or explicitly, we use models to make predictions of how the system will respond to any action we are considering.

In the wildlife-wind energy context, we are most likely to experience frustration with modeling when management objectives have not been fully defined, or the problem statement is not clear or fully defined, or the management options are not clear. Are we dealing with liability under the Migratory Bird Treaty Act? Are we dealing with the Endangered Species Act, which points more to a population level concern? Are the objectives related to one development alone or to the cumulative impacts across developments? Do we need to take into account competing risks from non-wind activities such as the coal industry, highway traffic, etc.?

Are the decisions to be based on a federal process or on a joint-decision process involving both industry and government? What are the competing management options? Is it a siting decision, a question of operational management decisions?

Whenever we use modeling within a decision context, the purpose is to take identified measures and make some prediction about them relative to the stated objectives. It also gives direction to post-construction monitoring – what needs to be measured in that context.

To conclude, the usefulness of any model or modeling exercise is going to increase as clarity and transparency of the decision-making process increase. All stakeholders need to be clear about problem statement, need clearly specified objectives, clearly defined set of management options from which to choose.

### [Tony Starfield](#) (University of Minnesota, emeritus)

Others have said much of what I wanted to say, but I will put these ideas through my own lens.

Why model? Because you have got to be able to make good decisions and communicate them to people in a complicated world. If you don't model explicitly, the ensuing debate and the way people make decisions begins to look a lot like politics: everyone has different, implicit models running in their heads, and nobody knows how each model works. So if we are to make better decisions together we need to be explicit and transparent in our modeling.

What is a model? It is a virtual world – a simplified world – constructed with a very definite purpose, such as making a decision.

Consider this “virtual” PowerPoint slide: picture a graph in which the horizontal axis is *understanding* – how well do I understand the processes involved in the problem I am trying to solve. *How do Indiana bats forage? How do raptors funnel through the Alleghenies?* The vertical axis is labeled *data*. How much data do we have, and how good is it?

Now let us divide this graph into four quadrants. In the upper left quadrant, we have very little understanding but quite a lot of data. What do you do in that situation? You call in a statistician and try to squeeze some understanding out of all that data. If you find yourself in the upper right quadrant, that's ideal. Here we have a lot of data and also a good understanding of the problem we're trying to solve. Jason Jones' presentation is an example of this overlay of behavioral understanding with data.

Most of the problems we're talking about here are in the lower left quadrant: we have very little data AND very little understanding. What do we do in that situation – as scientists, as regulators, as wind

energy developers? Here are some ideas about how we can use modeling to bootstrap ourselves up from the lower left towards that upper right-hand corner.

All of these ideas come with a general caveat: be very, very careful!

Keep in mind that the graph I just described actually has a third dimension: what is the purpose of the modeling exercise? The objective – what exactly are you trying to model and why – should be what drives the model.

What do you do if you don't have any data? You have to invent some data. You have to make some best guesses. And if you don't have much understanding of the phenomenon in question, you have to make some assumptions. Understand that the effect of guessing at data and making assumptions is that your uncertainty is greater. My advice is to keep the model simple, so that you can concentrate on the implications of different data (within the range of plausible values) and assumptions for the decision in question. The question to ask is: Within the context of my very clear objectives, would different data (or plausible alternative assumptions) change my decision? If so, then I either have to make a different decision, or make an interim decision that will allow me to gather more data. Likewise with assumptions.

All of this points to the need for keeping your model as lean and simple as possible. The more complicated the model, the harder it is to do the assumption analysis or the data sensitivity analysis. Every model has to see through all the details to the skeleton of the problem, so that you can see the underlying structure and assess where you can lean on it.

### ***Modeling is ultimately the art of the possible.***

So it is important to recognize in which quadrant of that virtual graph your problem lies, to figure out what one can possibly do with a model, and to explore how you might then bootstrap up, ideally working together with other stakeholders. One prototype, and then one thinks about how to improve the prototype.

Two final pieces of advice:

1. ***When you have a difficult problem – divide and conquer.*** It is better to develop focused small models with very specific purpose, than to create a very complicated model that doesn't allow you to do the data sensitivity or assumption analysis.
2. ***What would you have done if you didn't have a computer?*** Thinking about what you would do without a computer forces you to be clearer about what your real objective is and what you need to get at it.

## Questions & Discussion

### ***Regarding Trevor Peterson's models with Indiana bats – it is implicit in conservation plans that we will see cumulative and landscape level models...***

Peterson: For bats, we have been forced to come up with an “acceptable level of mortality” which requires us to attempt an extrapolation to population size, but at the same time we have to acknowledge that there is great uncertainty.

***What do people think about developing frameworks in the absence of data? Is it time to start developing population impact models?***

Pastorok: It is not always necessary to think of the total spread or abundance of a population. It's much easier to think in terms of modeling population density.

Grzybowski: Modeling is useful in that it provides a way to structure a system – even with limited data, modeling can provide starting points, and provide some structure for understanding the missing pieces.

Starfield: It is always helpful to build a model just to see if your thinking works in the sense of being logical and addressing the problem. In the case of population density – I would try to define a smaller problem. For example, I might want to explore whether a particular habitat is a source area, and then ask whether some action you are considering will turn it from a source into a sink. Look at smaller problems. Divide and conquer.

Comment: The nice thing about models is that you can do sensitivity analyses, and figure out where in their life stage animals are sensitive to impacts.

***Lacking demographic data for bats, has anyone thought about piecing together life cycle information from carcasses coming in from white-nose syndrome? In other words, if you don't have life cycle information for any bat species, and if you could build one species' life cycle, you would have a starting point.***

Peterson: Are you talking about bats most prone to collision or bats most prone to white nose? [The thought is, if you don't have life cycle information for any bat species, and if you could build one species' life cycle, you would have a starting point.]

Johnson: One caveat would be that the animals most susceptible to disease may not be representative of the species in terms of life cycle.

Comment: There is something to the idea that “poor data well organized is better than good data poorly organized.” [Panel members concur.]

Pastorok: It is useful to look at species in terms of their life history characteristics. This has been done in the context of superfund sites and evaluations of pesticides and examples are in the ecological risk assessment literature. It's a good place to start when you don't have detailed demographic data for a particular species. One doesn't need to do ecological risk assessment for every species which may be of concern. Choose the species that are representative of a particular life history.

Comment: However, consider Mallards, a very well-studied species. Hunting kills a lot of Mallards every year, and we've been trying to study population effects, but we still don't know whether hunting mortality is additive or compensatory – whether it makes any difference to Mallard populations. I would offer that as a caveat to people who want to look at population impacts for lesser known species.

Kendall: True, but the major point is that there are four competing models about Mallard population dynamics. On average, those models come up with pretty good predictions for where population is going to be the next year. In some ways, it may not matter whether the model accurately reflects the species biological life cycle, provided it allows you to make a good prediction.

Grzybowski: Today's presentations have focused mostly on methodology. Do you expect that your results will corroborate each other's work or show vastly different results?

Forcey: We are less than one year into a two-year project. I think we're asking different questions, so it may not make sense to look for corroboration from our results.

Peterson: The time required to get results depends very much on the scale of model. Some are on a small scale, some looking at a very large-scale.

Starfield: The history of the fishery by-catch problem suggests that you will eventually come up with darn good mitigation methods, probably before the biologists figure out precisely what's going on. Modeling can be good and useful, but focus on mitigation efforts.

# Session 5. Cumulative & Landscape-scale Impacts to Specific Species or Groups

Moderator: Doug Johnson, *USGS Northern Prairie Wildlife Research Center*

## ***Correlation of Bat Acoustic Activity to Bat Mortality in the Eastern United States***

[Gino Giumarro](#), Stantec Consulting, Inc.

(Co-authors: Kristen Watrous, Trevor Peterson, Sarah Boyden, Joseph Johnson, Stantec Consulting)

[Link to Presentation](#)

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**Research objectives:** Validate assumptions about whether regionally collected acoustic bat data can be used to predict migratory activity at wind energy sites, and whether that activity is correlated with bat mortality.

**Key terms:** acoustic detector, bats, *Lasiurus*, *Lasionycteris*, migration

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This presentation focuses on validating our assumptions about bat migration in the Northeastern United States using acoustic bat data. Stantec has collected a large amount of data from the eastern United States. Our dataset includes acoustic bat data from more than 80 wind power projects from multiple years. However, along with that large dataset comes a great amount of uncertainty about how many bats are being detected and whether acoustic bat activity levels can be correlated with mortality at utility-scale wind energy facilities.

Three species of long-distance migrants – the hoary bat (*Lasiurus cinereus*), the silver-haired bat (*Lasionycteris noctivagans*), and the eastern red bat (*Lasiurus borealis*) – are of greatest concern at wind facilities, since they are not only migratory and have the potential to be exposed to numerous wind energy sites, but they are also the species with the highest rates of mortality.

In evaluating assumptions about migratory ecology, we started by focusing on what we don't know. There is currently little known about bat migratory routes or their behaviors, but we can use acoustic bat activity levels to tell us something about migratory timing. If it is possible to use acoustic bat data to better understand migratory timing in tree-roosting bats then perhaps we can begin to predict the timing and magnitude of mortality at wind energy sites.

### **Methods**

Between April and November 2007 and 2008, we used acoustic detectors to record activity above the forest canopy at one existing and 13 proposed commercial wind energy facilities in 7 eastern U.S. states. At each site, acoustic detectors were positioned at two heights: at the level of the rotor swept zone (40-50 m) and above the canopy (or, in the absence of trees, at 20 m). During the two years of survey, we

identified 6,802 eastern red bat calls, 1,908 hoary bat calls, and 2,603 silver-haired bat calls during 6,153 detector-nights. Species calls are easy to identify by looking at call sequences.

Slide #6 shows the areas included as part of this analysis. We first grouped survey locations into three geographic regions – Northeast (5 sites), Northern Allegheny Plateau (4 sites), and Mid-Atlantic (5 sites) – then compared bat activity patterns at survey locations within and among regions. Data are summarized as calls per detector per night. Slide #7 shows the pair-wise correlations within each of three areas for silver-haired and hoary bats. No correlation was found for red bats.

Slides #8-10 show examples of what these correlations look like with regard to bat activity. Ignore the magnitude; what are important are the peaks in activity and the correlation in the timing of those peaks. Sites from different regions show different patterns. In slide #10, blue lines show activity occurring further north, where peaks occur earlier; green lines show activity occurring further south, where peaks occur later. We also noticed some “funneling” of activity – i.e., tighter correlations – further south. This may be an indication of the congregation of bats along their migratory route.

One lesson from this data is that each species needs to be handled separately, as their peaks of activity occur at different times. See slide #11, which compares activity indices for hoary versus silver-haired bats in the mid-Atlantic region. Silver-haired bat activity peaks earlier.

### ***Activity and mortality***

We also compared bat activity at a ridgeline with bat mortality at an operational wind facility an adjacent ridgeline 5 km away. We took the mortality data for red, hoary, and silver-haired bats from an operational facility and acoustic data from the adjacent ridge in 2008 (Young et al. in 2009). For silver-haired and hoary bats, we found a correlation between acoustic activity and mortality. For eastern red bats, we did not find correlation between acoustic activity and mortality – but given our other results, we don’t know if this is a question of detectability or behavioral characteristics.

### ***Conclusions***

This research did not yield any big surprises, but now we can look at these patterns and correlations on a broader scale, particularly for hoary and silver-haired bats.

The most meaningful implication of this work is that we can use acoustic bat data for something more than just checking off a box (yes there are bats / no there are not). Acoustic data can be used to measure the timing of bat migration across a geographic range. We’re at the stage now where we want to reach out in a collaborative way to share that with other researchers. Ultimately, a collaborative acoustic data warehouse may be the pathway to answer some very specific questions – within and across sites – about individual species.

Discrete regions must be considered through factoring or stepwise paired regression, and the data for each species need to be treated separately.

While we are not there yet, we may eventually be able to use the huge network of acoustic detectors that exists out there to create an “AnaBat early warning system.”

## Questions & Discussion

### ***Do you think altitude impacts migration as much as latitude?***

Giumarro: We are trying to figure out how to tease that out of our radar data, but right now I could only make a wild guess.

### ***How did you get your detectors placed at rotor swept height?***

Giumarro: The easiest way is to have a pulley at the top of met tower. We also deployed detectors on the outside guy wires.

### ***Was there a difference in correlation between the higher and the lower detector? If so, what were the differences, and would you recommend one over another for monitoring?***

Kristen Watrous: We have not looked at that yet.

### ***What percent of calls were you able to identify to species and how do you think this affected your correlation analysis?***

### ***How did you identify silver-haired bats? (How distinguish from big brown bats?) How accurate do you think your method was?***

Giumarro: With certain data sets we got a high percentage of good calls, and some with less identification. We were very conservative in our call identification and used a multiple researcher interpretation system to reach blind consensus on call based on their characteristics.

### ***Did you record bat activity at the wind energy facility itself, or just the adjacent ridge?***

Giumarro: From the adjacent ridge.

### ***Was your correlation within region calculated with data on each night? If the bats are responding to weather, are you simply showing that weather is similar at the sites?***

Giumarro: There was correlation of regions for the acoustic activity for individual species. There is no doubt some effect of weather, but our early analysis has not shown strong correlation with weather data on a regional basis, suggesting that they weather alone does not explain variation between sites.

### ***Was your correlation within region calculated with data on each night?***

Giumarro: We used nights as sample size.

### ***If the bats are responding to weather, are you simply showing that weather is similar at the sites?***

Giumarro: Weather fronts could create favorable conditions for bat migration. Generally, we are looking at weak correlations, so we are not making any broad sweeping biological conclusions at this point in our research.

### ***Studies, including yours, show higher fatality in fall than spring. What hypotheses do you have to explain this behavioral difference?***

Giumarro: We have just educated guesses at this point – perhaps because spring migration is more dispersed while fall migration is more concentrated?

***Based on your experience, what technique is better at predicting mortality risk at a wind energy facility, acoustic or radar?***

Giumarro: That depends on a lot of factors. You cannot use a radar system for looking at little brown bats. Neither is best for looking at mortality. [Presenters Donald Solick and David Young concur.]

***For your acoustic activity correlation figures, were acoustic data from high or low or combined detectors?***

Giumarro: Combined detectors.

***How many bat species do we know utilize echolocation during migration as opposed to use of visual cues?***

Giumarro: There is a big question with regard to red bats. All bats are echolocating to some degree during migration, but some use echolocation more than others.

***Were the acoustic detectors set up in a similar manner at all the sites you discussed?***

Giumarro: Yes, the set up and housing was similar and they were at similar heights and pointed in similar directions.

***How many AnaBat detectors per site? Just two? What were you correlating?***

Giumarro: Two per site, but the correlations were made between sites, not between detectors at a particular site. We have done preliminary tests to determine if all above canopy detectors gather the same activity trends. Our qualitative analysis is that we get the same species for above canopy detectors, but that the magnitude of calls detected differs.

***At what level of “r” do you consider a correlation to be biologically relevant OR statistically supported? Please relate this to your statement regarding activity and fatality correlations.***

Giumarro: We generally used some low statistical standards at this stage in our research. We considered weak correlations of 0.2 to be meaningful enough to begin targeting future research direction.

## ***Determining Potential Take of Indiana Bat from Wind Energy Facilities***

[David Young](#), WEST, Inc.

[Link to Presentation](#)

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**Research objectives:** Determine a defensible means by which reliable and realistic estimates of potential take of Indiana bat can be made for wind project to inform Endangered Species Act compliance actions.

**Key terms:** Indiana bat, HCP, Endangered Species Act, take

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In the fall of 2009, two events occurred that changed wind power development in the eastern U.S., a Federal court determined that operation of a proposed wind facility in West Virginia would lead to take of Indiana bat, and an Indiana bat fatality was recorded at an existing wind facility in Indiana. These two events elevated the scrutiny of Indiana bats throughout the species' region (see slide #3).

The Endangered Species Act (ESA) has provisions by which an Incidental Take Permit (ITP) may be acquired to cover "take that is incidental to, and not the purpose of, carrying out an *otherwise lawful activity*." Exceptions to the take prohibition under the ESA are in Section 10 of the act and include Enhancement of Survival permits (e.g., for purposes of research or recovery) and safe harbor; and Incidental Take Permits (ITP). Applicants seeking an ITP under Section 10 need to develop a habitat conservation plan (HCP) that details impacts likely to result from taking of a listed species, and therefore, they must be able to explain how incidental take will be calculated.

How does one determine how incidental take will be calculated (i.e., the number of animals potentially killed, harmed or harassed) for something that we have basically no examples on which to base our best guess?

Section 10 (HCP guidance) offers two methods for calculating incidental take:

1. in terms of the number of animals to be "killed, harmed, or harassed" if those numbers are known or can be determined; or
2. in terms of habitat acres or other appropriate habitat units to be affected by the project, in cases where the specific number of individuals is unknown or indeterminable.

### ***Habitat equivalency approach***

Is the "habitat equivalency" approach appropriate as a basis for incidental take estimates for Indiana bats? This approach requires:

- a strong correlation of habitat with species presence; and
- data available or collected related to density or abundance or the species per unit of habitat.

Some Indiana bat habitat is well-defined: they generally prefer forested areas, and roost habitat and hibernacula are readily identified. However, some take is likely to occur outside of defined habitat, i.e. due to collision with turbines, so this approach is not ideal.

### ***Number of animals***

In the absence of data related to direct impacts, there are two acceptable means to estimate take in terms of the number of animals:

1. surrogate species approach
2. collision risk model approach

The surrogate species approach utilizes spatial occurrence and behavior data from similar species to estimate take of the focal species. This approach is useful when there is existing data for the surrogate related to a project, and when impacts are defined for the surrogate.

As shown in slide #19, tri-colored and little brown bats appear to be good surrogates for Indiana bats. They are similar species, have an overlapping range, and there are a lot of data on both these species. To apply the surrogate approach using these species, we also need to know the ratio of the two species

on the landscape, region, or project area; and to have documented presence of the surrogate in the project area. The ratio of the two species can then be used to estimate the expected impact to the focal species from the level of known or expected impact to the surrogate.

Slide #21 shows the process by which information about collision mortality for the little brown bat can be used as a surrogate to determine take of Indiana bat.

The *collision risk modeling approach* uses site-specific or general data collected on habitat use, spatial occurrence, and/or temporal occurrence of individuals across the landscape or project area to predict impacts. This approach assumes that risk is a function of 1) the frequency of Indiana bats flying within the “zone of risk”, and 2) the probability of collision or barotrauma.

There are sophisticated statistical means to predict frequency of occurrence within the zone of risk. Resource Selection Function (RSF) models, in simple terms, determine which landscape/habitat variables are the best predictors of known locations of individuals (the response variable). This modeling can define areas across a project or region with the best characteristics for species occurrence. Activity indices, based on acoustic data or radio telemetry, can also be used to predict occurrence and define temporal patterns of occurrence within the zone of risk. For assessments involving bats and wind turbines, a study design using an array of sampling stations across the ground and elevated on towers can provide the necessary data to model bat use in three-dimensional space.

Having established that an Indiana bat and a wind turbine are likely to be in the same location (frequency in the rotor-swept area), the second step is to determine the frequency of collision. Modeling the actual strikes is appropriate in situations with little empirical data on collisions. Computer simulations can be used to define collision risk potential by flying a computer-simulated animal through the wind project. Model inputs would include the size of the animal, the size of the turbine RSA, whether the facility consists of a single string or array of turbines, travel speed and direction, as well as assumptions about the bat’s avoidance or attraction to turbines. Model output is in the form of collision probability estimates.

### **Conclusions**

Is there a best method for determining take? The decision depends on many variables, the most important of which are the availability of data and ability to collect data. While habitat-based impact assessment has merit, it is unlikely to provide a fully defensible estimate of take in the light of impacts occurring outside of impacted or occupied habitat. Surrogate species and collision risk modeling utilize existing and collected data. The choice depends on which assumptions can you live with the best? The two approaches also can be combined to corroborate the level of estimated take.

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## Questions & Discussion

***Using a surrogate species approach, what if the ratio of Indiana bats to surrogate species is much higher than your example, e.g., 1:2? Are mortality estimates still reasonable using this method?***

Young: If you choose to use this approach, you have to be comfortable with your data and believe the ratio of surrogate to species of interest is accurate.

***In estimating take, did you consider how far Indiana bats fly from wooded riparian corridors into open areas toward turbines?***

Young: In a collision risk model approach you could use a resource selection function to tease that out. The surrogate species approach is based on available impact and occurrence data.

***Is bat behavior less predictable than bird behavior? We've been told that a collision risk assessment wasn't possible for the hoary bat in Hawaii, because of the bat's unpredictable behavior.***

Young: Predicting animal behavior is difficult at best but the available data on impacts to bats at wind turbines seems to indicate that there may be some behavioral risk factors that elevate risk for some species such as hoary bat.

## ***Use of Marine Radar to Study Bat Movements\****

[Donald Solick](#), WEST, Inc.

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**Research objectives:** Evaluate the use of marine radar as a tool for tracking bat movements, particularly in the context of wind energy development.

**Key words:** marine radar, bats, *Tadarida brasiliensis*, colony

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Marine radar has proven to be an effective tool for studying the flight patterns of birds and insects, but few studies to date have used this technology for studying the movements of bats. In 2008, we had the opportunity to use marine radar to study a large colony of Brazilian free-tailed bats *Tadarida brasiliensis*. Examples of radar observations from that work highlight advantages and disadvantages of using marine radar in the context of studying bat-wind energy interactions.

### ***Description of the technology***

We use a commercially-available X-band antenna mounted on the top of a van, where it rotates in a horizontal position. With each sweep of the antenna the information is updated so that objects that are moving leave a trail (shown as blue marks on the monitor screen) behind them. This allows us to determine the location of target at a given time, and also track the direction and speed of targets. A technician sits in the van recording data on a laptop, and we also capture video footage of the radar display.

### ***Examples – radar positioned at a distance***

The radar footage presented here is part of an ongoing study of a colony of about 100,000 Brazilian free-tailed bats. We monitored the colony for several hours at dusk and dawn to capture both emergence and reentry of bats from their cave. We monitored from a position about 5 km away from colony, and also at the cave entrance itself. Two video clips are described:

1. An emergence event is captured in horizontal mode at a range of about 6 km. In the display, the radar is at the center of the circle, and the bat colony is designated with a red star, about 5 km

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\* Slide presentation not available as part of this Proceedings.

to the southeast. Bats emerging from the colony appear as a cloud of yellow and blue that gets larger and moves towards the west.

2. Switching to vertical mode allows us to look at a cross section of the cloud of bats as it moves between two orange parallel lines. The view is enlarged so that the screen radius is 1.5 km, making it easier to see the bats. A red line indicates ground level, the radar is in the center of the screen, and large yellow dots in blue boxes represent 125-m tall wind turbines (depicted for scale only). Bats occupy a relatively narrow range of air space between 0 and 250 m altitude.

### ***Advantages and limitations of the technology***

At a distance of 5 km, we found we could track a large number of bats and measure various attributes: directional heading, flight speed, area covered, median height. By putting these data into a GIS we can see how bats disperse across the landscape in relation to topography, weather, and other variables. This information could be helpful for assessing collision risk or developing mitigation strategies based on bat behavior.

In the course of conducting 20 surveys over a four-month period, we found that we could detect emergence events more easily than re-entry events, which are more dispersed in space and time. Emergence events were easier to detect in the summer than in the fall, when bats move in smaller numbers rather than in tight formation and are therefore harder to detect from a distance.

Another limitation is that in the vertical mode at 5 km, the radar is sampling just one slice of sky. If bats do not fly through that band, we get no information.

### ***Additional examples – radar positioned at the colony***

We also used the radar to capture emergence at the colony itself. With the radar in horizontal mode, the colony is indicated on the screen by a red star, 300 m from our radar. The screen radius is again 1.5 km. This example demonstrates some of the limitations of radar observation. The bat colony is located in a rugged area with a lot of ground cover that creates clutter on the screen, as well as a cliff face that creates a shadow zone. Bats come from the center and fan out towards south, with a different group emerging from another exit and moving towards the northeast.

Coverage at the colony was better with the radar in vertical mode. In the example shown, bats emerged in tight ribbon formation and flew at a height of 100 meters. To give an idea of the variation we observed, a second vertical-mode video shows the same location on the next night – emergence is much more dispersed, and the bats are flying up to altitudes of 600 meters before leveling off.

A third video shows vertical-mode coverage of bats returning to the colony just before dawn. In this case, bats appear to drop out of the sky like meteors from flight altitudes of between 100 and 250 meters.

### ***Implications for using radar to study bat-wind interactions***

Two other studies have used marine radar to study bats. Both were looking at the impact of wind development on large concentrated populations of bats – essentially because radar technology does not allow us to distinguish dispersed populations of bats from nocturnal birds without employing an additional technology.

See, for example, Greg Johnson's presentation (p. 21) of a recent study of bat migration at a wind energy facility in the Midwest. This study used marine radar to collect data on passage rates, flight direction and altitude, while night vision goggles and bat detectors mounted on turbine nacelles were employed to help distinguish bats from birds in the rotor swept area. These data were combined with weather data and fatality searches to determine bat mortality, so that we were able to find some evidence for increased mortality on nights when passage rates were higher and flight speeds were lower.

Angela Sjollem has found some evidence for bat activity over the ocean using radar (see presentation summary, p. 145), and others have found similar evidence in Europe. This raises the question of risk from offshore wind energy operations.

There is some evidence that bats tend to avoid areas with concentrated radar activity, so marine radar may have some utility as a deterrent device. Along the Gulf Coast, radar is also being tested as part of a "first alert" system.

### **Conclusions**

Marine radar can be a useful tool for studying bat movements, and can be a useful tool in helping biologists address ecological and applied (i.e., wind energy) bat research questions.

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## Questions & Discussion

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### ***How did you know when you missed emergence – did you look outside and see the bats emerging?***

Solick: Yes; essentially, we had someone stationed at the colony itself with whom we were in radio contact, so we knew when emergence occurred.

### ***If bats' flight path is erratic, yet we require three consecutive observations in the same direction to define a target, how many bats will be missed?***

Solick: With this application we did not even attempt to count targets – we called them clouds.

### ***Can you explain why bats fly at different heights (100-650 m) when they emerge from the colony?***

Solick: No, not really. Free-tailed bats are variable in their behavior. Sometimes when they emerged in very dispersed patterns, it correlated with a storm front or calm winds.

### ***Based on your radar at the bat colony, what setbacks might you recommend of turbines from the colony?***

Solick: I do not have a recommendation – it comes down to the situation at a particular site. You need to assess each site-specific situation.

***You showed bats passing at an altitude within the rotor swept zone of a nearby wind facility. Do you have any knowledge concerning Brazilian free-tailed bat fatalities at the site? Or potential risk of developing a site so close to a large colony?***

Solick: There was no wind facility there; we just showed superimposed pictures of wind turbines in the vertical radar video to show scale. That is not to say that there isn't risk to Brazilian free-tailed bats – they make up 22% of fatalities in the facilities where Brazilian bats are known to be active.

***Can marine radar be used to record eagle use within the rotor swept zone?***

Solick: Yes and no. Turbines themselves generate interference, making it harder to see things within the rotor plane. You might be able to see targets approaching, but you wouldn't necessarily know their height. So yes, there is some potential, but there also are limitations.

***Why can't you adjust radar to eliminate ground clutter?***

Solick: That's a good question. I don't know – we haven't found anything yet that works.

***Could individuals (bats) be detected by attaching a hyper-reflective material to a bat?***

Solick: I don't think so. They're just tiny blobs. I do not think that is feasible with our radar technology.

***Is bat behavior less predictable than bird behavior?***

Solick: I would have to say yes.

***Did you calculate a measure of relative abundance in your study?***

Solick: No. However, it may be possible to get at relative abundance by looking at density of targets. This would likely require some sort of imaging software approach.

***Could the 0% return back into the cave each morning during September and October have been related to the bats leaving/migrating elsewhere?***

Solick: I don't think so. To clarify, re-entries were not seen on the radar when we were parked 5 km away (with the exception of 2 nights during the entire study period). When we were stationed at the colony with the radar, we had no trouble detecting re-entry. So I think it is more likely that the reason re-entry wasn't detected at a distance is because bats were returning throughout the night and were more dispersed in space and time than during emergence.

***How sensitive was your setting on the marine radar? Did you have a filter set?***

Solick: Sensitivity: Pulse1 S2P. We did not have a filter set.

***How did you verify you were seeing bats on the radar?***

Solick: On nights the radar was stationed 5km away we had an observer stationed at the colony who would communicate with us when the bats were emerging, and what approximate direction(s) they were heading. We would subsequently see one or more clouds of targets emerging on our radar screen from where we knew the colony to be, and track those clouds under the assumption they were bats. When these clouds passed over the radar van, we often could look outside and see bats flying over, as well. So while we didn't have a set procedure for confirming we saw bats, it is highly unlikely that

anything else in the atmosphere would have appeared in the sky at dusk at the precise location of the colony and traveled across the landscape in such a manner.

***How does your radar differ from DeTect's units?***

**Solick:** We use an X-band antenna for both horizontal and vertical surveillance, whereas DeTect uses an X-band for vertical coverage and an S-band for horizontal coverage. The S-band can pick up smaller targets further away, but by that same token is more likely to pick up insects and small debris and may have a harder time discerning targets close to the radar. The hardware itself is the same – this is off-the-shelf equipment. However, while we use the same software interface that comes with the hardware, DeTect has developed its own proprietary software interface.

***Evaluating Changes in Bat Activity and Species Composition from White Nose Syndrome at Fixed Acoustic Monitoring Locations in Vermont***

[Kristen Watrous](#), Stantec Consulting, Inc.

(Co-authors: Eric Britzke, U.S. Army Corps of Engineers; Ryan Smith and Scott Darling, Vermont Fish and Wildlife Department; Susi von Oettingen, U.S. Fish and Wildlife Service; Sarah A. Boyden, Stantec Consulting)

[Link to Presentation](#)

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**Research objectives:** Evaluate the relationship between results of a 3-year acoustic bat monitoring study with the simultaneous loss due to white nose syndrome (WNS) of 80-90% of overwintering bat populations within selected hibernacula in the state thought to contain large portions of the state's population of certain bat species.

**Hypothesis:** We would expect to see a decline in bat activity between pre- and post-WNS acoustic survey results.

**Key terms:** acoustic, bat activity, pre-construction survey, Vermont, White nose syndrome

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White nose syndrome (WNS) was first detected in 2006 in Schoharie County, NY, and has since spread to at least 115 bat hibernacula, causing 30-99% mortality. (Slide #4 shows the progression of the disease south and west from New York State.) This emerging disease attacks the exposed skin of hibernating bats, causing more frequent arousal during hibernation, apparently leading to starvation.

WNS was then documented in southeastern Vermont during the winter of 2007-08. Mortality associated with WNS has been documented at 80-90% in selected hibernacula in the state. Mortality has resulted in the identification of new hibernacula, and the increasing of assumed population size in known hibernacula. The largest hibernacula in Vermont had an estimated population size of 23,000 bats, but more than that have been found as carcasses on the floor of the cave. Over one million bats are estimated to have been killed to date. It is vital to verify and model expected declines in northeastern bat populations due to the possible future extirpation of local or regional populations.

It is difficult to assess the population-level impact of WNS because we don't know the initial population size for the affected species. Are there other indices that we can use to measure population decline?

To document potential declines in acoustic activity due to WNS using consistent methods between years, we augmented a two-year acoustic survey of bat activity on Grandpa's Knob in Vermont that was conducted during the summers of 2007 and 2008 with a third summer of acoustic surveys in 2009. The initial surveys happened to have coincided with the arrival of WNS in the area, giving us an opportunity to document changes in acoustic activity potentially related to the onset of WNS. These intensive studies include one season pre-WNS (2007), one season during the first year of WNS (2008), and one season during the second full year of WNS (2009). Collectively, this work represents the most intensive acoustic survey conducted in Vermont to date and provides an opportunity to test whether documented population declines are reflected in acoustic bat activity levels.

### **Methods**

Data were passively recorded from mid-May to mid-August, between the hours of 7 pm and 7 am. We used discriminant function analysis (DFA) to identify acoustic files to species. Our acoustic detection surveys focus on high-frequency echolocators, which are more often detected down at ground level.

### **Findings**

A bar graph (slide #8) shows three years of acoustic data (all species) from five detector locations. Average activity (number of files per detector night) was lowest in 2009 at all but the South met tower detector. (The preceding year, 2008, was a period of high disturbance at the met tower site, so it may be that site disturbance and clearing accounts for this anomaly.) Overall acoustic activity increased from 2007 to 2008 at two of the detectors, decreasing at the remaining three sites.

For high-frequency echolocators, we saw similar patterns as for overall activity, with activity increasing from 2007 to 2008, then falling off sharply (to below-2007 levels) in 2009. Acoustic surveys continued this past summer.

Species-specific activity (slide #10) shows seasonal patterns. There was no activity in May of 2009. We hypothesize that bats may be taking longer to get to their summer habitat if they are stressed during hibernation because of WNS. Likewise, activity continues to increase into August – longer than usual in 2009. Are the bats trying to pack in more calories before migrating to hibernate?

### **Conclusions**

We did not see as much of a decline as we expected. Many other factors contribute to year-to-year differences. We will continue to monitor this year.

There is not a linear relationship between bat echolocation calls and the number of bats present. We do not know how they choose their foraging behavior or how long they stay. If there are fewer animals because of WNS mortality, it is possible that remaining bats remain longer at a given foraging location because it can accommodate the smaller number of animals. Likewise, surviving bats could be concentrating at better foraging areas, and so not be seen at all at poorer foraging habitat.

## Questions & Discussion

Watrous: I would love to talk with people who have collected acoustic data from pre and post WNS periods, to collect more data.

***A 30-90% reduction in Myotis in some hibernacula does not equate to a 30-90% reduction in the population. Do you have direct measures of the population? Some hibernacula may have escaped WNS.***

Watrous: What we have is derived from known hibernacula. We are discovering more hibernacula than we knew about when sick bats emerge during the winter and folks report them.

***Can you get at the effect of weather and insect abundance variation on high-frequency species activity by looking at yearly variation in low-frequency activity levels?***

Watrous: We hope to look at that information, but have not yet wrapped the low-frequency activity data into the equation.

***Did you look at weather when comparing years of calls. Vermont had a very, very rainy and stormy summer in 2009. Could this account for the decrease in call numbers?***

Watrous: Yes; that's why we continued gathering data in 2010.

***You highlighted "no activity for May" during 2009. That May was cold and wet in the West; what was the weather like where this data was collected, and how would that factor into your results?***

Watrous: May usually is rainy and cold in Vermont, so I don't know that it made any difference.

***Define "average activity per night." Is it the number of minutes of activity/night/species, or the number of bat calls/night/species?***

Watrous: The activity index is the number of files recorded/number of operational nights for each detector for a month.

***What is disrupting hibernation patterns of bats dying of WNS?***

Watrous: It is thought that the fungus is somehow irritating the bats, but we don't know. Skin probes show elevated skin temperature and spores do enter the skin, but how that works to stimulate arousal we don't know.

***Did you look at any variability estimates (such as bootstrapped estimates) for activity rates? In other words, are your differences in activity true differences? Did you perform any statistical analysis on your temporal trends?***

Watrous: We are waiting for the 2010 results in order to conduct a full statistical analysis.

***How did you address / consider annual variation in bat activity, which can be several-fold?***

Watrous: We are hoping to include weather data (wind speed, temperature) as a covariate in future statistical analyses.

# Session 6: Mitigation Techniques and Technology

## Mitigation Techniques and Technology, Part 1

**Moderator: Jerry Roppe, Iberdrola Renewables**

In this session we will be looking at mitigation techniques and their applications. [This session is broken into two parts, with Diane Ross-Leech moderating the second half.]

Understanding cause and effect is important to us being able to move toward practical solutions. Whatever mitigation hierarchy is used, the goal is to get applied research on the ground and reduce impacts and provide a proof of concept that can be applied to the operations. We have to understand the effect of a mitigation technique on operations as well as on the wildlife resource.

### ***Using a Predictive Indiana Bat Habitat Suitability Model to Inform a Tiered Curtailment Strategy for an Ohio Wind Power Project***

[Cara Meinke](#), Stantec Consulting, Inc.

(Co-author: Kristen S. Watrous, Stantec Consulting)

[Link to Presentation](#)

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**Research objectives:** Create a curtailment strategy based on empirically-tested data that maximizes protection of the Indiana bat while allowing for an economically viable wind energy project. Test efficacy of the curtailment strategy with long-term monitoring program which provides for adaptive management to adjust specific operational curtailment levels and periods to which they are applied.

**Key terms:** curtailment, foraging, habitat assessment, Indiana bat, Mahalanobis technique, roosting

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This presentation reports on the use of a predictive habitat suitability model to inform a tiered curtailment strategy to avoid and minimize impacts to Indiana bats at a wind energy project in Champaign County, Ohio.

#### **Overview**

The evidence of bats being killed at forested ridges in the mid-Atlantic region as well as in the Midwest in agricultural settings underscores the need for effective techniques to avoid and minimize these impacts. There is particular concern for the Indiana bat, which has been on the federally endangered list since 1967. Indiana bat numbers fell 57% between 1965 and 2001. There was a slight increase in Indiana bat populations between 2001 and 2007, but it is still very much endangered. Habitat loss and degradation, climate change and now White-Nose Syndrome all threaten this species' viability.

To date, wind development has taken place mostly in the eastern part of the Indiana bat range, but more development efforts have recently been focused in the Midwest, which contained two-thirds (66.7%) of the range-wide Indiana bat populations in 2009. There has only been one Indiana bat fatality documented in post-construction mortality monitoring studies to date, during the fall 2009 migration period in Benton County, Indiana. *Myotis* fatalities at wind facilities have generally been low (~10%). However, several studies at wind energy facilities in largely agricultural settings in New York State have reported higher proportions of *Myotis* mortality (~20%). While overall bat mortality at these facilities was generally low (5-9 bats/MW/year) a recent study at a Wisconsin site documented the second highest bat mortality at a wind facility to date (22 bats/MW/year; not including incidentals), with 30% of the fatalities being *Myotis* bats. These studies could indicate an emerging trend of higher than expected *Myotis* mortalities in facilities located in agricultural settings, which describes much of the Midwest.

Curtailement has been shown to substantially reduce bat mortality in several studies. Most bat activity takes place when wind speeds are less than six meters per second. Studies show that when operational cut-in speeds are increased from turbine manufacturer-recommended levels to between 5 and 6.5 m/s, bat fatalities are significantly reduced (between 44% and 93% reductions over non-curtailed turbines). The fact that similar reductions were observed in areas as geographically diverse as Pennsylvania, Alberta, and Germany holds promising support for broad application of this technique. But this must be balanced against the loss of power generation and the project's economic viability.

### ***Predictive Habitat Suitability Model***

We considered three habitat suitability models. The Indiana bat HSI model has several limitations: it involves little or no empirical data; requires site-specific measurements; lacks consideration of landscape patterns; and assumes equal importance of all variables. Other habitat suitability models are based on presence/absence, and are therefore problematic for rare species.

The Mahalanobis D2 Technique offers several advantages. It relies only on presence data only, has landscape-scale applicability; is predictive; and variables are weighted according to relative importance. This technique is used and has been published in peer reviewed literature for a wide variety of species, including black bear, black-tailed jackrabbit, Sage Sparrow, Acadian Flycatcher, California Gnatcatcher, timber rattlesnake, and the Indiana bat.

### ***Application of model***

We used a partitioned Mahalanobis D2 model based on 1,124 nighttime radio-locations and 43 roost locations from 19 Indiana bats radio-tagged in the vicinity of a wind energy project area in Champaign County, Ohio, during summer mist-netting in 2008 and 2009. (The Ohio Department of Natural Resources is the repository for raw data.)

We used a Geographic Information System (GIS) to measure spatial characteristics of forest patches, habitat heterogeneity, slope, elevation, and distance to stream, wetland, and forested stream within 2-km buffers of each pixel in the project area. There were a total of 13 environmental variables:

- Forest class
  - Forest patch area
  - Patch cohesion index
  - Euclidean nearest neighbor
  - Perimeter-area ratio
  - Percentage of landscape

- Total core area
- Landscape
  - Shannon's diversity index
- Distance Variables
  - Distance to forest
  - Distance to forested stream
  - Distance to stream
  - Distance to wetland
- Elevation
- Slope

The distances ( $D^2$ ) between the vector of environmental conditions measured at each pixel and the mean vector of environmental conditions at known Indiana bat roosting and telemetry locations were rescaled using a Chi-square distribution, converted to p-values, and divided into 4 quantiles, representing most to least suitable.

Indiana bat foraging habitat suitability was strongly associated with the configuration and spatial relationships of forested patches; the three most important variables were the degree of fragmentation (perimeter to area ration), the connectedness of forest patches, and the total core area of forested habitat. This differed from roosting habitat suitability, which was driven largely by distance to forested streams, distance to streams, and distance to the nearest forest edge. High quality roosting habitat was much more limited than high quality foraging habitat. Foraging and roosting suitability were mapped and combined on one map to show which parts of the project area have the highest probability of Indiana bat occurrence. (Slide #15 – green represents lowest probability of occurrence, red is highest probability.)

We then used these categories to come up with a tiered approach to operational curtailment – based on the predicted Indiana bat habitat suitability – at each proposed turbine location. Curtailment regimes differed in terms of cut-in speeds, duration, and seasonality, with turbines located in the most suitable Indiana bat habitat having the highest cut-in speeds (6 m/s, referencing other studies) applied over the longest duration. Cut-in speed was stepped down in areas of successively lower risk. Note that this model is applicable only to the summer reproductive period and not to the spring and fall migration; different curtailment strategies will be used during the migration periods.

### ***Applicability of model***

This model allows for predictive mapping over large areas using readily available data.

A similar modeling approach could also be used to identify migratory habitat and pathways, which is important because fall migration period is when we expect there is higher risk. However, there is still a lot we don't know about how Indiana bats migrate and future data collection efforts, such as spring and fall telemetry studies, would strengthen the reliability of potential migration models.

### ***Future research***

We need to improve confidence by applying this model to known records of Indiana bat occurrence, and comparing model predictions to the data.

We need more landscape-scale studies so that we can identify ecologically significant areas and prioritize management actions.

There needs to be data sharing and collaboration among state, federal and private entities.

## Questions & Discussion

### ***What time of day and time of year will curtailment apply?***

Meinke: From half hour before sunset until half hour after sunrise. The plan I've described here was designed only for the summer reproductive period (June 1-July 31). A separate plan will be applied for the migration periods.

### ***What is the advantage of curtailment in the summer breeding period when most fatalities have been reported in the fall?***

Meinke: Bat mortality at wind facilities during the summer period has generally been much lower than that observed during fall migration, and the effectiveness of curtailment during this period has not been specifically tested. However, this project has the potential to affect Indiana bats, a federally endangered species. Therefore, it is necessary to design minimization strategies that are conservatively protective of the bat. Adaptive management will be used to modify the seasonality of the curtailment strategy if it is found that curtailment is unnecessary during the summer reproductive period.

### ***How does model address migratory season? Given where the single Indiana bat mortality was found, it would seem entire area is potential migratory habitat.***

Meinke: Yes, the whole area is considered migratory habitat. As stated previously, the tiered curtailment strategy that I presented was only applicable to the summer reproductive period. Different curtailment strategies will be applied to turbines during the spring and fall migration periods that will be tailored to addressing the relative risk during these seasons.

### ***What is the relationship between Indiana bats and forest fragmentation? Do they prefer edges and more fragmented landscapes, or more forested?***

Meinke: The model showed that larger, more contiguous forest areas, in close proximity to other large forest areas (i.e., less fragmented areas) were most similar to the foraging habitat used by radio-tagged bats in the study. Conversely, large, unforested areas (i.e., agricultural areas) were the least similar to the foraging habitat used by radio-tagged bats. Areas that were closer to forested streams and streams were most similar to roosting habitat used by radio-tagged bats, but distance to forage edge was also important.

### ***How does your model deal with differences in detection among landcover types and probability of use without information on availability of different habitat variables?***

Meinke: The model does take into account differences in land cover types, but not in terms of their relative availability in the landscape. The model is not a use vs. availability model, which has been used in several studies to describe habitat use. The Mahalanobis technique does not make any assumptions about what is or isn't available to the bats. Rather, it works by prioritizing areas as most suitable based

on their similarity to areas where radio-tagged Indiana bats were located during roosting and foraging activities.

In terms of the vegetation information, we used the National Landcover Database to derive information about Indiana bat use of forested habitat, as well as their habitat use relative to the diversity of all habitat types in the study area (expressed as the Shannon Diversity Index). We focused on their use of forested habitat because the vegetation system in the study area is very simple. It is basically either agricultural/hay/pasture habitat (82% of the area) or forested habitat (8% of the area); there is a very small proportion (~10%, with 6% being developed open space) of other habitat types.

***How did you evaluate your habitat classification system? Did tracked bats use your classified habitats in proportion to their ratings, or were bat locations used to define your classes?***

Meinke: The latter part of your statement more accurately describes the way the model works; areas with habitat conditions that were most similar to the habitat used by radio-tagged bats were classified as most suitable.

***How did you establish your take estimate at your Ohio project?***

Meinke: We used a collision risk model that was based on both empirical data and expert opinion.

***In designing the Ohio project, was consideration given to moving turbines out of more suitable Indiana bat habitat, thereby avoiding more impacts and allowing for lower cut-in speeds?***

Meinke: The project is using a combination of avoidance and minimization techniques to reduce impacts to Indiana bats.

## ***Texas Gulf Coast Avian and Bat Fatality and Curtailment Approaches\****

[Wally Erickson](#), WEST, Inc.

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**Research objectives:** Evaluate the effectiveness of MERLIN radar system and episodic turbine curtailment to reduce avian mortality, especially during spring and fall migration.

**Key terms:** curtailment, Gulf Coast, Merlin radar, Texas, bird mortality

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The Peñascol Wind Project and the Gulf Wind Project are the first wind energy facilities located along the Texas Gulf coastline south of Corpus Christi and Kingsville. Because of well-documented nocturnal migrant fatalities at communication towers during bad weather, as well as concerns over mortality of waterfowl, water birds and other birds along the gulf coast, research and monitoring were undertaken at both facilities. This project is a joint research project conducted by TX-ESA, EcoStats LLC., and WEST.

One mitigation strategy that is being implemented and tested is a turbine curtailment program. A Merlin avian radar system and visibility monitors have been installed at both the Peñascol Wind and adjacent Gulf Wind projects. The systems actively interface with the turbine operations software, implementing

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\* Slide presentation not available as part of this Proceedings.

turbine curtailment when risk factors of low visibility and high biological target passage rates exceed certain thresholds. Studies are ongoing to evaluate the effectiveness of this approach, and to implement adaptive management to modify and improve on these approaches.

### ***Study components***

Methods used to help evaluate the curtailment strategy as well as understand collision risk include fatality searches, evaluation of continuous radar data collected on site, and evaluation of other risk factors such as weather and location.

Daily fatality searches are conducted using dogs at 14 turbines at each site during the spring and fall migration periods. Searches are conducted at 16 turbines (at 8-day intervals) at each site year round. Initially, we searched circular plots centered on the turbine and extending 67.5m (221 ft) on each side. The radius was increased to 100 m in the summer 2009 –a 225% increase in search area. Extensive bias trials were also conducted. Biologists conduct random, abbreviated surveys at individual turbines, and have been tasked with determining if large-scale mortality events are correlated with high target (high passage rate) events.

Weather/high risk forecasts are conducted to prepare operations for potential curtailment events, and a tool was developed to help turbine operators to understand when curtailment is likely (primarily during periods when high target rates and low visibility). Risk is categorized as low, moderate, and high, solely based on weather conditions and assuming migration is occurring at all times. During a two-month period last spring (March 15-May 15, 2010) moderate conditions occurred on 16 days, and high risk conditions occurred on two days. At these times, a biologist was sent to the site to observe the weather and biological activity at the radar site. We are currently evaluating fatality data relative to our risk indicators.

### ***Curtailment inputs and criteria***

Curtailment criteria, developed on the basis of pre-construction data, were as follows:

- The target count within the rotor swept zone reaches 37 targets/1-km front/2 minutes, and
- Visibility is less than half a mile.

The MERLIN system is used to count targets. It includes both horizontal (HSR, or s-band) scanning radar – capable of searching further out, but with a lower detection rate for smaller birds – and a vertical (x-band) radar with a 1.5 km radius scan. Both the radar data and input from visibility sensors is fed into the wind turbine SCADA system, which is programmed to send a command to shut down the turbines when the criteria are met.

Curtailment is lifted at the Peñascal site when either the passage rate or the visibility criterion is no longer met for a period of at least 15 minutes. For the Gulf Wind site, curtailment is lifted when visibility resumes for at least 15 minutes.

### ***Preliminary findings***

During spring 2010, five curtailment events occurred at the Peñascal site. None occurred at the Gulf Wind Site. During initial operation of the radar at Peñascal, the system logged some false positives, but the continual improvement of the radar tracking software and system has to date reduced or perhaps eliminated incidence of false positives. We are seeing target altitudes consistent with what has been observed elsewhere, with most nocturnal migration occurring well above turbine height.

Fatalities recorded are shown in the table at right; larger birds are highlighted. Note that we were unable to get a permit to salvage carcasses, so we were not able to identify all of the fatalities, as noted in the table.

The rates presented here are from the spring period only. Higher numbers of bat fatalities are being found in the fall, but we have not yet estimated adjusted numbers.

A very limited observation study at Gulf Wind looked at changes in cut-in speed. During a three-week period in September, cut-in speed was increased to 5.5 m/sec from 6 pm to 9 pm and 5 am to 8 am at a subset of turbines. The data are too limited to make strong statistical inferences; however, observed results were consistent with other studies: observed bat mortality at curtailed turbines (2.0 per turbine unadjusted) was less than half that of fully operational turbines (3.8 per turbine unadjusted)

Species	Penascal		Gulf Wind		Both Sites	
	#	% Comp	#	% Comp	Total	% Comp
Yellow-breasted Chat	21	12.1	3	2.4	24	8.0
Mourning Dove	10	5.7	10	7.9	20	6.7
Turkey Vulture	8	4.6	6	4.8	14	4.7
Red-eyed Vireo	9	5.2	2	1.6	11	3.7
unknown Empidonax	5	2.9	3	2.4	8	2.7
White-tailed Hawk	3	1.7	4	3.2	7	2.3
Northern Parula	6	3.4	1	0.8	7	2.3
Barn Owl	3	1.7	2	1.6	5	1.7
Northern Bobwhite	4	2.3	1	0.8	5	1.7
Sora	3	1.7	2	1.6	5	1.7
White-eyed Vireo	1	0.6	4	3.2	5	1.7
Baltimore Oriole	2	1.1	2	1.6	4	1.3
Hooded Warbler	3	1.7	1	0.8	4	1.3
American Redstart	1	0.6	2	1.6	3	1.0
Indigo Bunting	3	1.7	0	0.0	3	1.0
Kentucky Warbler	1	0.6	2	1.6	3	1.0
Magnolia Warbler	0	0.0	3	2.4	3	1.0
Yellow Warbler	2	1.1	1	0.8	3	1.0
Unknown bird	60	34.5	52	41.3	112	37.3
Total	174	100.0	126	100.0	300	100.0

### ***Difficulties/confounding factors***

One challenge for this approach is that it is hard for the x-band radar to distinguish bird, bat and insect targets. (Insects are a big issue on the Texas Gulf Coast.) Other challenges:

- Visibility sensors need to be cleaned on a regular basis – a maintenance cost
- Integration and communications among the various systems (radar, visibility systems, turbine SCADA system)
- Environmental challenges – corrosion, heat, decomposition rates, feral hogs, rattle snakes, tropical storms/hurricanes, surface water, rapid growth of dense ground vegetation

From a statistical standpoint, the greatest challenge is that we are trying to test and predict rare events.

### ***Summary***

These are preliminary data. We have not been able to test whether curtailment works here; in another year we may be able to say more about relationships. Key points:

- The curtailment system is operational, but integration continues to be refined and improved.
- We are still analyzing the fatality, radar and other data to determine/develop relationships, with the goal of optimizing curtailment criteria.
- No federal T&E species were found.
- No “large fatality events” were recorded at either site.
- Very few waterfowl, shorebird, or raptor fatalities were found, including no Redhead fatalities.
- Lighting effects are not apparent (consistent with other studies).
- Lack of a permit to collect carcasses leads to multiple counts of the same carcass; current plans call for mowing of search plots, which may compensate for the difficulty of searching this terrain.

## Questions & Discussion

### ***Can you reiterate your mortality search interval and period (# days between surveys and survey period)?***

Erickson: Daily searches during spring and fall migration (14 turbines); 8-day search interval year round at 16 turbines.

### ***The overall per turbine and per MW estimates of bird mortality seemed really low compared to other sites. Do you think the impact justifies this large mitigation expense?***

Erickson: Estimates given were just for the spring period – we need to complete study to determine whether it is a valid way of reducing mortality.

### ***Did you estimate the percent success of the dog searches for fatalities at the sites?***

Erickson: Texas ESA did the field studies with dogs. Initial detection rates were lower, but over time they improved. I don't have the numbers in front of me, but I believe searcher efficiency was about 50-80%, depending on size of bird.

### ***Why was 37 targets chosen as the curtailment criterion – what was that based on?***

Erickson: It was based on the top ten percent of counts during pre-construction studies at Gulf Wind over a whole year. We were trying to determine the upper 90<sup>th</sup> percentile of counts – all passage rates for the year – trying to discern the central part of migration season, highest passage rate amounts. This curtailment strategy was designed to reduce very large mortality events similar to those that might have been seen at communication towers.

Roppe: It was just an initial number selected to get the ball rolling...

### ***Why were the curtailment criteria different at the two sites?***

Erickson: One system prioritized visibility – we felt that may be a driver, and wanted to assess if there was a separate effect.

### ***Who initiated the curtailment option – the regulator or the developer? What was the motivation?***

Roppe: There was concern by regulators and NGOs, and a common interest in finding out how to resolve those concerns. Everyone involved was trying to be very transparent and collaborative in working on an adaptive management approach.

### ***The “real time” warning via radar is limited to the 4 km distance for horizontal or 1.5 km for vertical mode. Given the airspeed of these species, is there enough warning time to have blades come to a stop by the time targets arrive at the site? (At the normal blade speed, how long does it take from the time the curtailment command is given for blades to come to a total stop or reach a negligible speed?)***

Erickson: Our current criteria are established to trigger curtailment when there appear to be a lot of birds arriving in the area. When the 37-target threshold triggers the warning, it takes 1-2 minutes for turbines to be curtailed. The radar is located such that the small area of birds that trigger that warning is

already part way through the wind project. The idea is that there is a ramping up of targets – the 37-bird trigger suggests there are a lot of birds coming overall, and if there is also low visibility, that’s when we want to curtail the turbines.

***Do you have mortality counts at Gulf Wind project during the time during which curtailment occurred at the Peñascal Project? If so, what are they? And why do you think the two projects have different mortality rates?***

Erickson: We have such small numbers – the sample size is too low to make any inference on it. Why the difference between the two sites? There is more fresh water on the north (Peñascal) side; also this is just one year of a multi-year study, so it is too early to make a conclusion about that.

***How was the visibility criterion measured – i.e., how was it determined that visibility was less than 800 m?***

Erickson: Horizontal and vertical ceilometers were set up at the site.

***Did you take into account decreased probability over range?***

Erickson: We did not. Vertical 1.5 km radar gives us some indication that there was not a big drop-off of detection. Horizontal radar is not being used currently with the curtailment programs.

***Did you experience any interference and false alarms due the turbines?***

Erickson: Those locations are masked out so blade tips don’t get picked up by the radar.

***How were the number of tracks within rotor swept zone derived, given MERLIN radar does not render 3D data?***

Erickson: Horizontal radar was not used; we used vertical radar to get target counts in the rotor height zone. (S-band and x-band sensors are independent – they are not used to get 3-d data.)

***Curtailment appears effective for bats, but birds collide with fixed communication towers, buildings, and other non-moving objects. Do you have data on the potential effectiveness of curtailment for reducing bird mortality?***

Erickson: There is a higher probability of collision for a turbine that is in operation, however the probability is not necessarily that much larger for operating versus a stationary turbine, especially if there is not any attraction to a turbine. Based on studies conducted at wind projects, turbines and the associated lights do not appear to be an attractant. Therefore, if the probability of collision without attraction is not that different between operating and non-operating turbines, curtailment may not be as effective for birds. More research is needed to understand this. Data collection and results have not been completed to test for potential effect of curtailment on birds at these projects. .

***Was there any visual confirmation during the 5 curtailment events to determine whether there actually was heavy bird usage (as opposed to, say, insects)?***

Erickson: There was not any visual confirmation.

***Would you recommend this technology at most wind sites? Why?***

Erickson: The technology needs to be demonstrated to be effective through experiments at wind projects. This is the first such experiment and much additional experimentation is needed.

***Do you anticipate refinement of curtailment triggers?***

Erickson: Yes after modeling the relationships between weather, radar and mortality which will occur this winter.

***Siting of turbines in coastal areas is often avoided because of fear of high risk for avian mortality. Were you surprised that only about 300 carcasses were recovered, given the assessed risk?***

Erickson: These studies reported on are the first year of a multi-year study. The results of the initial year of study suggest mortality was not high the first year of study.

***Reducing Bat Fatalities at Wind Energy Facilities\****

[Edward Arnett](#), Bat Conservation International

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**Research objectives:** This presentation reports findings from ongoing studies on the effectiveness of operational curtailment and acoustic deterrents to reduce bat fatalities.

**Key terms:** acoustic deterrent, bat fatalities, cost, curtailment, cut-in speed

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Unexpectedly high numbers of bat fatalities have been reported at utility-scale wind energy facilities – especially along forested ridge tops in the eastern United States. This raises important concerns about cumulative impacts of proposed wind energy development on bat populations. Based on discussions at this conference, perhaps we should stop talking about “mitigating” and shift the focus to “reducing” bat fatalities. Given the lack of population data, we can demonstrate that we have reduced fatalities, but not that we have mitigated them.

As we look at wind energy development and bat mortality, we need perspective on the numbers of fatalities. Assuming a continental average of 12.5 fatalities per MW, and extrapolating to a U.S. goal of 20% wind power-generated electricity (approximately 350,000 MW installed by 2020), bat fatalities could theoretically reach 4.3 million fatalities per year under several assumptions. This would not likely happen, but we have to ask whether bats can sustain such rates of mortality. Given the magnitude and extent of bat fatalities worldwide, and the potential for cumulative effects on this scale, it is clear that we have to implement mitigation options.

Mitigation starts with doing pre-construction assessments. We have been doing studies since 2005, but it is difficult to draw any definitive conclusions about siting at this time, as more data and analyses are needed. In some cases it is obviously a bad idea to site turbines, but often we just can't tell. The jury is still out on whether we will be able to effectively predict fatalities from pre-construction observations.

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\* Slide presentation not available as part of this Proceedings.

Once a site is built, mitigation options become very limited. I will present results from curtailment and deterrent studies and discuss future research needs and efforts.

### ***Curtailment***

To date, curtailment is the only viable option that has been demonstrated empirically to be a valid mitigation strategy. This is curtailment during high-risk periods that may in fact be predictable. We know that peak bat kills tend to occur in the fall, and it tends to happen on certain nights in the fall. So these may be very predictable events. In 2004 at both the Mountaineer facility and the Meyersdale facility, we documented that a large percentage of kills occurred on those low-wind nights when energy production tends to be fairly marginal. When wind speeds are below the cut-in speed, blades stay in a feathered position, free-wheeling slowly – and there is pretty good evidence that bats are not hitting stationary or slow-moving objects. We could hypothesize various reasons that might be, but the bottom line is that it makes sense and the research bears that out.

We posed the hypothetical question: what would have happened if turbines had been curtailed on nights when the median wind speed was 6 m/s or less? Our hypothetical analysis demonstrated that roughly an 80% reduction in fatalities at those facilities would have occurred had turbines been curtailed on nights when the median wind speed was less than six meters per second. The problem is that there is no way to know in advance what the median wind speed will be on a given night. So we shifted the question around to ask: Would changing the cut-in speed reduce fatality of bats?

Manufacturers usually set the cut-in speed at 3.5-4 m/s. In Germany, studies have shown a 50% reduction in fatalities by increasing the cut-in speed to 5.5 m/s. In Alberta, Canada, studies have shown a 60% reduction by changing the cut-in speed to 5.5 m/s.

Testing the hypothesis - We tested multiple cut-in speeds at Casselman wind energy project in south-central Pennsylvania, with the objective of quantifying the reduction in bat fatalities at two alternative cut-in speeds (5 and 6.5 m/s), relative to the economic cost of the lost power.

We did daily searches of 12 experimental turbines, looking for fresh-killed bats linked to the previous night's treatment. Ten other turbines were also being searched at the same time as part of another ("PGC") study. We re-randomized our treatments each night of the study, so that for each of three treatments on each night (fully operational, cut in at 5 m/s and at 6.5 m/s) there were four replicates, with the night as the experimental unit in the analysis. A comparison of fresh-killed bats among treatments was modeled as a Poisson random variable using general linear mixed model with turbines as a blocking factor.

In both years of the study, and contrary to our prediction, we found no difference in bat fatalities between the 5.0 and 6.5 m/s treatments during either year of the study. However, we found little differentiation in the amount of time different cut-in speed treatments were in effect, which may explain in part why we found no difference in bat fatalities between the two treatments. We combined the treatments for our analysis, and in 2008 we found 2-14 times more fatalities for fully operational versus (combined) curtailed turbines. This represents about a 52-93% reduction in fatalities for curtailed versus no treatment. Results from 2009 were consistent with 2008. Again, fully operational turbines killed 2-7 times more bats than the combined treatment turbines, resulting in 44-86% more bat fatalities.

Cost of curtailment – The experiment represented approximately 2% of total project output during the 75-day study for 12 turbines (~0.1% of total annual production). But what is more interesting and important is to project what would happen to production if we had applied the treatment to all 23 turbines at the site. Hypothetically applying each of the two treatments to all 23 turbines for 75 days:

1. 5.0 m/s = 3% of 75 day period; 0.3% of annual total
2. 6.5 m/s = 11% of 75 day period; 1% of annual total

Conclusions and next steps – We need to look at testing different curtailment options in different regions, at all-night versus partial-night curtailment, and we need to fine-tune those treatments with temperature and other types of variables which might better predict when we would want to curtail.

### ***Acoustic deterrent***

Another possible post-construction mitigation strategy is to generate an acoustic, ultrasonic deterrent – what we commonly refer to as the “bat-be-gone.”

Laboratory studies showed that an acoustic deterrent reduced bats’ feeding ability. We also saw reductions of activity at ponds relative to a short distance – reasonably significant reductions and sustained effect with no habituation. The next step was to scale it up to mount a device on an Iberdrola turbine nacelle.

Of 64 turbines available at our study site, ten were fit with a total of eight deterrent devices each on the nacelle: three devices were fit to each side of the nacelle and pointed downward into the rotor swept area; and two were aimed at a reflector plate to send ultrasonic emissions into the upper part of the rotor swept area. These turbines were searched each day from mid-August to mid-October in 2009 and 2010. During this same period, we also conducted daily searches at 15 different turbines that were part of a complementary study to determine post-construction fatality rates and to meet permitting requirements of the Pennsylvania Game Commission’s (PGC) voluntary agreement for wind energy (herein referred to as “PGC” turbines). These 15 turbines formed our reference turbines for comparing with deterrent turbines. We compared average fatality at PGC with treatment turbines using one-way analysis of variance with each turbine as the experimental unit and  $\log_e$  (estimated total fatalities) as the response.

In 2009, we found 20-53% fewer bat fatalities at the treated turbines than at the controls. In other words, the acoustic deterrent was not as effective as the curtailment strategy. In fact, the effect of deterrents is within the range of variation that we see from turbine to turbine. In 2010, we also looked at all turbines simultaneously from May to July to determine if there were inherent differences between treatment and reference turbines. Our preliminary analysis suggests there is not a difference between the two sets of turbines. Based on raw numbers from 2010, it appears that we are likely to see similar effects of the deterrents as we did in 2009.

Research and development of acoustic deterrent devices is continuing. We still do not have a functional device that could be deployed. We need to maximize the airspace – to put out as many of these devices as we can – and see what happens. What we did these last two years cost about \$20,000 per turbine, just for the equipment and installation. A new experiment maximizing the number of deterrents on each turbine could reach up to \$30-35,000/turbine for the next experiment. Industry will need to be able to maintain these devices once they are mounted on the nacelle, so this cost needs to be included when calculating the economics of deterrent devices.

## **Conclusions**

Operational curtailment studies indicate that bat fatalities can be reduced from 44 to 93% during selected high-risk periods of the year and with marginal power losses (0.3 to 1% of total annual output). Research and development of acoustic deterrent devices is continuing. With curtailment in particular, the classic question is, how much is enough? Industry can work out financial thresholds, but what is the biological threshold? This is a very challenging question; we need more information about bat populations to be able to answer it. Again, we know we that we can reduce bat mortality, but without knowing more about the population, we don't really know if we've mitigated the impacts.

## **Questions & Discussion**

### ***Is there anything similar to the “bat whistle” for birds?***

Arnett: I don't think so – anyone from bird community?

Manville: There was a study (Engstrom, 2000) that looked at using infrasound. It seemed promising, but nothing more has been done with this.

Roppe: Spain has commercial systems for large birds, called a “detractor” system, but it has not been studied.

Larkin: A study looking at reactions of birds to sounds broadcast from the ground (1978-83) found that Swainson's Hawk paid no attention to the sound of a predatory bird, but always turned away from thunder sounds – but only if broadcast on a cloudy day.

### ***Do we know the wind speed at which small bats (Myotis) don't fly, or at which 90% of them don't fly?***

Arnett: We have only separated and analyzed our data by high and low frequency bats, but one could further analyze the data by species if they have analyzed calls to species and have sample sizes needed to run the analysis. Our data indicate that there are still a lot of calls recorded at wind speeds above 6 m/s.

### ***Do you have any recommendations on what level of bat fatalities (per MW) warrants curtailment discussion?***

Arnett: Any such number is not currently backed empirically because of the lack of population data. Having said that, we need to put forth such thresholds in an adaptive management context and as testable hypotheses. Very few agencies have set such thresholds, but there are examples from Canada and there are discussions happening among many state and federal agencies.

### ***Please explain the difference between cut-in speeds and feathering.***

Arnett: In my view, changing cut-in speed is the operational practice, or action if you will, and feathering is better used to describe the state or position of the turbine blades. Operators can manually change the SCADA systems to pitch the blades so that they are parallel to the wind – this is what is referred to as feathering. The blades are not locked, but move very slowly. The turbines themselves are automated to “feather” during certain conditions as well. For example, blades feather when wind speeds exceed the maximum wind speed rated for the turbine (I believe ~55 mph) or during very low

wind speed below normal cut-in. The study from Canada used full and partial feathering and found no difference between the treatments, but partial feathering (e.g., pitch at 45 degrees instead of 90) was considered less stressful and better operationally by the company. This warrants further testing.

***How does curtailment equate to dollars lost / reduced energy output?***

Arnett: Our analysis demonstrated 0.3% of the annual total with 5 m/s curtailment. There is a three-fold increase in energy output when you go from 5 to 6.5 m/s. We did not put this into a dollar figure.

***Do you have cost estimates for start-up or installation costs for the bat acoustic deterrent for a wind energy area?***

Arnett: We do not have these estimates available at this time and believe it would be misleading until we determine how deterrents are needed to achieve the maximum possible effect and what mounting strategy would be needed. At this point, operational expenses could be more accurately estimated.

***Do you have a sense whether curtailment or fitting with deterrents is more financially feasible?***

Arnett: The major difference is capital up front versus lost operation time. We don't really know now at this point in time, because those capital costs may come down, but you also have to figure in the cost of maintaining the equipment. If we could demonstrate reasonable effectiveness, mass production of deterrents will bring costs down. We need to estimate and compare long-term costs (permit term, e.g., 20 years) for both strategies in the future.

Roppe: It's good to think about what costs come into play – when we look at the cost of these deterrents, we should remember that we're looking at the prototype stage, and those costs may go down. But consider the cost of maintaining radar operation on Gulf Coast.

***For bat deterrents, what is the frequency of sound emitted?***

Arnett: Broad band 20-100 kHz.

***How far is the range for the deterrent (the one that "goes to 11")?***

Arnett: Right now, we're thinking we can affect the airspace in the ~50 kHz range out to about 20-25 m at best. Higher frequencies will be shorter, lower frequencies out further. Further R&D may yield better results in the future.

***Does the use of deterrent meet the definition of "harm and harass" in the ESA for federally listed bats?***

Arnett: As far as I know, no. But I don't know what the standard is. It could, but this is a question for the U.S. Fish and Wildlife Service.

***Are there any potential downsides to the use of acoustic deterrents? (For example, extra energetic expenditure during migration, any effects on non-target species?)***

Arnett: We are struggling with getting the frequencies out to the full length of the blades and beyond to have a greater effect on bat avoidance, so we do not believe the device can reach out far enough to have such deleterious effects on other species and even if so, it would seem to be a good thing if other creatures avoided the blades.

***Have you looked at species-specific response to your acoustic deterrents?***

Arnett: We do not have this available at this time, but will try to look at species-specific responses.

## Questions & Discussion – Mitigation Panel

The following questions were addressed to the Mitigation panel of presenters as a group:

- ***Are we ready to set policy based on this handful of studies? When do you know enough? Need to understand effects on operation and cost?***
- ***Can we take these data and apply it across all sites and conditions, or is this still a research question?***
- ***What can we take from this meeting? What can we extract from it?***
- ***Are you (panelists) ready to recommend the mitigation strategy you used at your site?***

Erickson: The work at Gulf Coast Wind in Texas is the first of its kind; we have yet to determine whether we are ready to make recommendations. It may be that nocturnal migrating animals are not at risk on a scale that we're concerned about except in very rare instances.

***Based on what you know, is it worth looking further at this?***

Erickson: It is worth doing more studies, yes; but we also need to do more analysis of data that's already been collected. There are a lot of individual studies – 65 bird studies – out there; we could learn a lot from meta-analyses.

***Is there any evidence of how effective curtailment has been in reducing mortality?***

Arnett: How many studies do agencies need before they make a policy decision? I am confident that curtailment can reduce bat mortality, but I cannot say that it will be effective everywhere.

D. Johnson: What is the confidence level you would need?

Meinke: With our project, we had the rare opportunity of being able to apply a large pool of site-specific data; but unless that same kind of data is available in another area, I cannot say that I would prescribe curtailment everywhere.

Roppe: Let's talk about the term "curtailment." At the Gulf Coast, we are talking about an initial investment of half a million dollars in radar equipment. From an economic perspective, it may be simpler and more effective to just curtail during low-visibility conditions. I would recommend working with industry operations folks to look at options that make more sense operationally in a given site with given set of species concerns.

Lesley Hale, Ontario Ministry of Natural Resources: In Ontario, Canada, we have an operational policy to curtail. Post-construction monitoring is required for three years. If a facility reaches the threshold of 10 bats/turbine, operational mitigation is required – and an additional three years of operational monitoring.

Portuguese perspective: Most of the questions raised here are the same as what we are looking at in Europe. The same mechanisms are being tested, and the state of the art is more or less the same. Further studies need to be done, but there should be international cooperation. Wind energy facilities and affected species differ from place to place, but to the extent we can share our data, the more we can learn.

Dr. N. Scott Urquhart, Colorado State University: I have not worked much with wind energy, but with 40 years experience in statistics and with biologists, I have a few suggestions:

- **Government agencies** – don't require two consecutive years of monitoring, but two years with at least one intervening year. Find out what you learned the first year before monitoring the next year.
- **Permittees** – A lot of this mitigation requires randomized studies. Consider pooling resources to fund long-term experimental stations in at least a few locations around the country.

Larkin: I want to open the question of cost here. This is an industry growing as fast as any in the world now. It's a very wealthy industry that's grown on the basis of tax breaks. A turbine costs \$1 million. Ed's deterrent costs half a percent of the cost of the turbine, and it not only keeps bats away, it keeps the lawyers away too.

Arnett: I want to ask a question about the Ontario policy. If it is a requirement, what do you do when the estimates demonstrate below 10 bats/turbine (say, 7.5)? How does industry factor policy in to their planning?

Hale: We have only started implementing the policy this year, so we don't know yet. The confidence level question has been raised, but the policy people needed to come up with a number. We had an engagement with industry before we released the policy, and did not get a big push-back, and we felt that this approach would be beneficial to industry overall. It will be interesting to see what happens next year and beyond if any of these wind energy facilities do reach that threshold or come within the confidence interval of that number.

## Session 6. Mitigation Techniques/Technology, Part 2

**Moderator: Diane Ross-Leech, *Pacific Gas & Electric Company***

This is the continuation of yesterday's session, which focuses on applied research. We live by the "avoid, minimize and mitigate hierarchy" in everything we do through siting, micro-siting, and operational mitigation techniques.

***A System to Avoid or Minimize and Offset Negative Impacts of Development on the Lesser Prairie-chicken through a Spatially-based Planning Tool, Promoting Voluntary Offsets and Targeted Conservation Work: A Multi-Entity Collaboration in Oklahoma***

[Chris O'Meilie](#), U.S. Fish and Wildlife Service

[Link to Presentation](#)

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**Research objectives:** Create a multi-scale spatially-based planning tool designed to allow for proactive evaluation of anthropogenic impacts, promote voluntary offsets and targeted conservation work for an area sensitive species and candidate for federal listing under the Endangered Species Act.

**Key terms:** Lesser Prairie Chicken, habitat suitability mapping, Oklahoma, spatial-based planning tool

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The Lesser Prairie Chicken (LEPC) is an area-sensitive species that has been a candidate for Endangered Species Act (ESA) listing since 1998, and is under the management authority the Oklahoma Department of Wildlife Conservation. There has been an 86% reduction estimated in the LEPC's occupied range (slide #3 shows the historic and current range of the species). Within this range, landscapes may be defined along a continuum from high quality to low quality to "no habitat/no restoration potential." Some low quality habitat would be difficult and costly to restore; other landscapes, such as areas that have been invaded by red cedar, are not ideal, but could be restored easily to suitable habitat.

The LEPC population trend is declining, and there is a high degree of overlap between wind development potential, power line planning, and remaining LEPC habitat. Other significant threats to this species include uncertainty over the Farm Bill, traditional energy development, and other forms of habitat loss and fragmentation.

In a proactive approach, an interstate working group made up of the Oklahoma Department of Wildlife Conservation, the Oklahoma Ecological Services Field Office of the U.S. Fish and Wildlife Service, the Oklahoma Chapter of The Nature Conservancy, the Playa Lakes Joint Venture, the George Miksch Sutton Avian Research Center and the Office of the Oklahoma Secretary of Environment collaborated to develop the Oklahoma Lesser Prairie-Chicken Spatial Planning Tool (OKLEPCSPT).

### ***Spatial Based Planning Tool - description***

OKLEPCSPT is a spatial model that combines eight factors, including biological and ecologically relevant spatial data (e.g., lek locations, suitable and potentially suitable land use/land cover) and fragmenting features (e.g., oil and gas well locations, roads, transmission lines, etc.) that exist within the Oklahoma portion of the current and historical range of the LEPC. (For buffer purposes, the estimated range under consideration extends beyond the Oklahoma state border.)

Slide #8 shows a color-coded map, with a 30 sq. m/pixel resolution, generated by a set of raster files for the entire LEPC historic range. Summing the eight binary classification factors produces a ranking used to rate the suitability of land on a scale of 1-8, with a score of one (1) being land with the lowest importance, and eight (8) being land with the highest importance.

This information is updated annually, and is available in various formats on the Oklahoma Department of Wildlife Conservation's website. The website includes a detailed description of the OKLEPCSPT, small and large format maps, Google Earth files, and raster files for ArcGIS and other GIS-compatible software.

### ***Assumptions and limitations***

Given that some of the data sets are old and have high error rates, we took a conservative approach to species conservation. Lek data, for example, are old and incomplete, and the base land use and land cover dataset is dated (from 1991-93 satellite data). Assumptions and other limitations of the planning tool include:

- All of the factors selected for the model are weighted equally – there is no consideration given to the possibility that some factors may be more important than others.
- The relative valuation of the landscape for LEPC generated by the OKLEPCSPT is not definitive of LEPC occurrence.
- The model has no persistence thresholds; it does not allow us to address cumulative impacts. (A spatially explicit population viability analysis is needed.)
- The model does not address corridors for habitat patch connectivity, which is critically important if the existing population is to expand.

### ***Voluntary offset program***

Slide #21 illustrates how a voluntary in-lieu fee program is used in conjunction with the OKLEPCSPT to offset natural resource devaluation over time. The planning tool helps to establish a baseline, so that impact and corresponding resource devaluation can be measured and off-set funding secured (on a voluntary basis). Voluntary payments can be used to buy land or secure a conservation easement or management agreement. Specific recovery measures may include cutting of eastern red cedar, prescribed fire, cropland-to-grassland conversion, etc.

Slides #22-24 demonstrate an application of the voluntary offset program concept with the spatial planning model. In the example shown, a 120-MW wind energy facility consisting of 80 1.5 MW turbines with a 2-km buffer zone around the turbines yields a project area covering 16,488 acres. The area is mapped using the planning tool, and the number of 30-m pixels within each of the eight LEPC model landscape classifications is graphed in a histogram. In this particular example, there are no class 1, 2 or 8 pixels.

Slide #25 shows the restoration cost per acre for each of the eight land classifications. There is a fixed (non-scalable) per-acre cost to establish initial management infrastructure and provide for overhead and

maintenance over a 30-year period, and a scalable per-acre cost to purchase and restore LEPC suitable or potentially suitable habitat, implement LEPC perpetual conservation agreements, or implement conservation management agreements with private owners. We decided that model values 3 and lower are of no consequence to the species, but for model values 4 and above we've calculated a cost per 30-m pixel.

### ***Current applications***

In addition to informing the Oklahoma Department of Wildlife Conservation's Voluntary Offset Program, the OKLEPCSPT is being used by consultants and developers to look at siting of wind energy facilities, transmission lines, and communication towers, and by Federal and state agencies and NGOs to prioritize their conservation efforts, including land acquisition and habitat restoration.

By combining LEPC habitat value mapping with wind resource maps, we have identified 20 GW of wind energy potential in the 2.6 million acres that lie outside the LEPC range. Identifying the least-cost path for transmission lines is another application.

### ***Management implications***

This is a completely voluntary process, and we hope to keep it that way. Our objective is to keep the Lesser Prairie Chicken from having to be listed. These decision support systems and tools provide a proactive opportunity for conservation entities to inform planners of possible project constraints, and to avoid or minimize and offset impacts.

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## Questions & Discussion

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### ***What information guides your buffer distances with various land features (managed lands, overhead structures, etc.), and how did you decide to apply a 2-km buffer around wind turbines?***

O'Meilia: Absent specific information, we try to apply a logical approach to minimizing influence – for example, avoiding overlap with managed lands. There are recommendations on buffer distances from the literature coming out of Kansas. Al Manville's paper recommends a 5-mile buffer for leks. We have also tried to apply some of the values that came from Robel, Pittman, and Hagen. All these recommendations are open to some interpretation and scrutiny; we tried to come up with something that made sense.

### ***Regarding old lek data – have you considered seeking volunteer help to survey historic/current lek areas?***

O'Meilia: The state has a contract to get surveys done, so that lek data and land use/land cover is being updated.

### ***How successful has the Prairie Chicken planning tool been in avoiding siting conflicts? Have developers been volunteering?***

O'Meilia: Some projects that were already in the queue have gone ahead. We've had several developers tell us they've used it, and have moved projects where there were problems.

***Can you talk more about the least costs paths for transmission? The Hitchland to Woodward line you showed does not look like it would be the “least cost” in terms of your model’s ranking. Do you anticipate that your analysis could change the siting of this line?***

O’Meilia: That line actually runs along a highway corridor which has zero values in other factors. The least-cost path planning process is a GIS function – it works through that to pick out the lowest value path from first to end point. It does not avoid all effects, but it does minimize effects.

***How adaptable are your GIS models for other birds, specifically raptors with very different life-history, traits, and ranges? If adaptable, would you be willing to make the tools publicly available?***

O’Meilia: We have thought about that. Obviously for raptors you would have different factors. The LEPC is a good species for this approach because it stays in a fairly defined area, and that allows us to focus. We would certainly make the model available. The tool is in its second iteration, and is available publicly on the web [<http://www.wildlifedepartment.com/lepcdevelopmentplanning.htm>]. There is also an 80-page paper that describes its use.<sup>4</sup>

***It was suggested that burning is affecting the leks. Landowners have agreed to do rotational burning to see if this is the case. What do you know about this?***

O’Meilia: Fire is a naturally occurring and important ecological process in grassland and shrubland ecosystems. Fires that occur too frequently and in the wrong time of year can affect grassland bird production through the removal of nesting cover and/or destruction of nests. Using a system called Patch Burn Grazing, land managers can manipulate these ecological processes to benefit livestock production and wildlife habitat by burning only a portion of a management unit ever year, rotating that area around the landscape between years, ultimately providing for a wide arrange of vegetation serial stages, community composition and structural diversity.

***Have there been any “voluntary” mitigation fees paid? How are these funds used?***

O’Meilia: There have been no mitigation or offsets to date. Two projects have used the model to evaluate the potential effects, but have not used the cost structure provided in our voluntary offset program within the model description paper. Oklahoma Gas & Electric has provided funds to the Oklahoma Department of Wildlife Conservation (ODWC). Funds are used in three categories: land acquisition, conservation easements, and cost-sharing to do habitat restoration and improvement. Our primary consideration in defining this structured approach is that we have to find willing landowners, because 97% of the state is privately held land. We have a good relationship with land owners and wind developers, but we have to get the landowner to agree to implement our preferred practices.

***Will species other than the lesser Prairie Chicken be addressed in the future?***

O’Meilia: Informally, we are thinking that bats and karst-related issues are probably the next priority. (Eastern Oklahoma is a karst region that has federally listed bats.) As for raptors, we would need more detailed movement data, such as the 30-second telemetry data we saw described earlier.

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<sup>4</sup> Horton, R., L. Bell, C. M. O’Meilia, M. McLachlan, C. Hise, D. Wolfe, D. Elmore and J.D. Strong. 2010. A Spatially-Based Planning Tool Designed to Reduce Negative Effects of Development on the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) in Oklahoma: A Multi-Entity Collaboration to Promote Lesser Prairie-Chicken Voluntary Habitat Conservation and Prioritized Management Actions. Oklahoma Department of Wildlife Conservation. Oklahoma City, Oklahoma. 79 pp.

## ***How Does the Accuracy of Data on Avian Movement Vary with Radar Methodology?***

[Marc d'Entremont](#),

University of Northern British Columbia and Stantec Consulting Ltd.

(co-authors: Dr. Ken Otter, UNBC; Dr. Andrea Pomeroy, Stantec; and Naira Johnson, UNBC)

[Link to Presentation](#)

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**Research objectives:** This project tests marine surveillance radar digitization hardware and tracking software that is being developed for avian tracking and uses these to measure movement patterns of nocturnal migrants around wind turbine installations. Objectives are to provide: 1) a cost-effective solution for the collection and analysis of site-specific bird movement (radar) data; and, 2) a balance between data accuracy and manageability.

**Key terms:** avian tracking, bird migration, collision, radar

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Real-time analysis of radar migration data has a number of potential limitations: 1) the inability to record all targets on the radar screen during busy periods of migration; and 2) observer bias in recording accurate distance and bearing information from the radar. These limitations can lead to the perceived risk of collision with wind turbines being over- or understated.

The use of radar for monitoring bird migration around wind farms in British Columbia has progressed at a slower rate compared to research in the U.S. A greater interest in developing wind farms began approximately five years ago. Marine surveillance radars have been used since to look at site specific bird-wind interactions, but no consistent protocols have been developed or are being used at different sites. In most cases, radar data are being manually recorded, with observers watching the radar screen and recording the first and last bearing and distance for each target.

The University of Northern British Columbia (UNBC) has partnered with Russell Technologies Ltd (RTI) and Stantec Consulting to conduct on-site research to better understand how birds use the airspace and habitat around proposed wind energy developments in the Hart Range of the Rocky Mountains (northeastern British Columbia). Specifically, this research seeks to measure the movement patterns and behavior of nocturnal migrants in relation to wind energy facility sites in order to identify the collision risk.

This goal will be achieved by working with RTI to develop and test the marine radar digitization hardware and tracking software (called WinHorizon) that they are developing for avian tracking and then using these to measure movement patterns of nocturnal migrants. A second purpose of this work is to develop technologies for data analysis and look at how the accuracy of data on avian movements varies with radar methodology.

### ***Project location***

The Dokie Wind Project is located in north-eastern British Columbia, approximately 40 km northwest of the town of Chetwynd. The project, which is scheduled to come on line in the spring of 2011, consists of 48 turbines that will be sited on two of ridges that are 1200 and 1400 m in elevation.

### ***Methods***

Digitized recorded radar data, collected in both spring and fall migration periods in 2008, 2009 and 2010, are being compared using several different techniques to assess how these contribute to variation in the data. Data is being scored in one-hour sample blocks that are selected based on different relative densities (i.e., high, moderate and low passage rates). Approximately 20 hours of data from both the northward and southward migration periods are being analyzed. Prior to scoring the data, the recorded data from each sample block was examined in detail in order to establish a baseline record of all targets. Each sample block was then analyzed under different sampling methodologies, specifically two levels of manual scoring and two levels of using auto-tracking features in the WinHorizon navigation software (called ARPA tracking):

- Manual Scoring 1 - manual scoring in 'real-time' simulation for passage rates only;
- Manual Scoring 2 - manual scoring of passage rates plus marking distance and bearing of each target in real-time for the start and end of each track (essentially, what is being collected in field sampling);
- Auto-Tracking 1 – manually selecting each target, but then allowing WinHorizon to auto-track the target for the rest of its movements; and,
- Auto-Tracking 2 – fully automatic target detection, acquisition and tracking by the software.

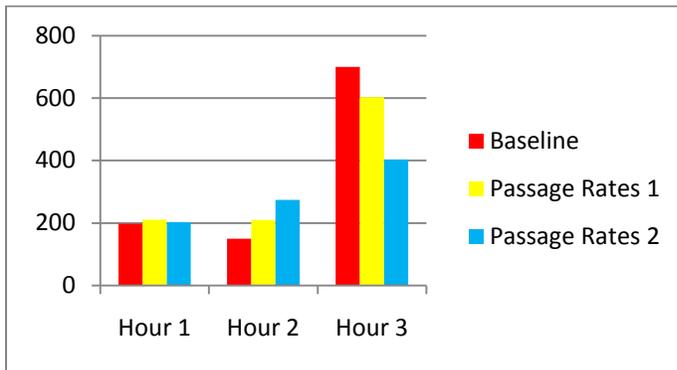
Scoring of data is being conducted by both the lead author and an independent research assistant to compare inter-observer accuracy. For each technique, the data on passage rates are being compared, as well as the tracks of the individual targets plotted in GIS for detailed comparisons of trajectories. The amount of variation (i.e., error and unreliabilities) between these trials will be identified through a repeatability analysis. Repeated measures models will be used to compare differences in total numbers of birds detected, and differences in trajectories of tracks calculated using the different techniques

### ***Preliminary results***

The WinHorizon software provides an affordable system, developed for use in a marine environment, that we have adapted to apply to bird tracking. WinHorizon is able to interface with most radar units and is able to track targets as small as passerines. The cost of the system including software is about \$5,000.

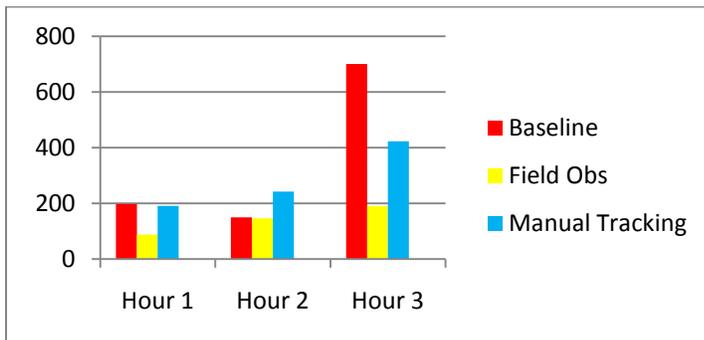
Given the time required for processing data, only three hours have been processed to date. For these hours baseline levels of passage rates and flight tracks have been identified. These are compared to manually recorded data, manually obtained passage rates and to the rates and tracks of targets acquired with the manual tracking functions. The preliminary results of these comparisons are in Figures 1 and 2.

**Figure 1. Preliminary results of comparing passages rates identified by lead author and research assistant.**



We are beginning to see a level of error between the analysis methods. For passage rates (Figure 1) there is little variation between baseline and the recording of passage rates only. So recording the real time passage rates of targets could be effective; however this only provides one component to measure collision risk. When looking at the detailed track analysis there is variability between baseline numbers and the manual tracking of targets using the recorded data. In two of the three cases both baseline and manual tracking numbers are much greater than the amount of data recorded in the field.

**Figure 2. Preliminary results of comparing data collected for detailed track analysis for baseline, manual data collected in the field and manual ARPA tracking.**



After increasing the sample size, further detailed analysis will be conducted to see if these preliminary trends continue. It is anticipated that the discrepancies between recording data in real time (manually) and using the auto-tracking acquisition to record data (digital) will increase exponentially as the density of bird passage increases. The added accuracy versus time requirement from using auto acquisition will be determined to see whether these features could compensate for the extra time required to record and back-analyze these data.

### **Next steps**

The next steps involved in this research include:

- Increasing the sample size (to about 20 hours of data)
- Refining the manual tracking feature of the WinHorizon software
- Conducting further analysis on the auto-tracking feature of the WinHorizon software
- Comparing the analysis of data with WinHorizon with other analytic software, e.g., radR.

We expect to publish our results in 2011.

## Questions & Discussion

***Auto-tracking with WinHorizon – does it ignore clutter, or does it try to track clutter – and if so, how do you deal with this?***

d'Entremont: The auto-tracking feature will attempt to track clutter. It will also try to track other things such as insects and moving trees. We are working with the RTI to refine capabilities of the WinHorizon software in order to overcome some of these issues.

***Can you set auto-track zone to cover the entire screen?***

d'Entremont: Yes, the auto-track zone can cover the entire screen, but targets that you don't want to track may be captured. So, the zone would typically be set to avoid areas of ground clutter and other noise.

***What levels of mortality are you seeing at the Dokie site, given that turbines are sited on ridges in a major flyway?***

d'Entremont: The turbines are not yet operational. They are erected but they have not been connected to the grid. Post-construction monitoring has commenced this fall but results are not available yet.

***What evidence is there that passage rate equals collision risk?***

d'Entremont: We don't have collision data yet. We are just trying to come up with a better tool to measure.

***Can you collect altitude data with WinHorizon?***

d'Entremont: Yes, we do have both. On average for nocturnal migrants, we are seeing them flying at 400-600 m above ground.

***Who produces the WinHorizon software, and is it used on both vertical and horizontal radar?***

d'Entremont: Russell Technologies Inc. is the company that developed the software, and we're working with them to refine it into a tool that can be used to collect digital data of targets the size of passerines. We do use it with both horizontal and vertical radar modes.

***Will your research try to determine how much data needs to be collected to characterize migration? Can too much data be collected with radar studies?***

d'Entremont: Yes, one of the outcomes of this research will be identifying what the optimal amount of data is and when this data should be collected in order to assess collision risk to birds at individual wind farms. In this case there is never too much data.

***Can you distinguish target size with your software? Does the software allow you to characterize targets according to their characteristics?***

d'Entremont: We can distinguish small, medium, and large targets based on their reflectivity values (0-255). Another component of my research will be to relate these reflectivity values to particular species

using discriminant function analysis. Apart from size (reflectivity), we can see some differences in flight movement patterns. We do not have much information; most targets are just bee-lining straight across. As time allows, we will be examining whether additional characteristics can be teased out of this radar data. Other applications might include working with airports – would they want to know what kind of birds are coming into their air space?

## ***Is it Necessary to Adjust a Wind energy facility Layout? A Proposal to Identify and Minimize Potential Impacts on Raptors and Soaring Birds***

[Ana Teresa Marques](#), Bio3, Lda.

[Link to Presentation](#)

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**Research objectives:** The main objective of the presentation is to demonstrate a methodological protocol developed to predict and evaluate the effects of wind farms on raptor and soaring bird populations, through the presentation of different case studies.

**Key terms:** Collision Hazard Index, impacts, pre-construction, raptors, risk

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Installed wind power capacity in Portugal is growing. In the first half of 2010, 18% of all energy consumed in Portugal was generated by wind turbines, mostly located in the northern part of the country and along some coastal areas.

Portugal is rich in biodiversity, with 25% of the country's land area protected, so ecological baseline studies are critical. Our company, Bio3, in recent years has been working on 23 Environmental Impact Assessments (EIAs), which in general are obligatory for siting wind energy facilities in the European Union. We are involved in 26 post-construction monitoring projects.

Pre-construction studies are part of the site selection process. We look at flora and habitats as well as fauna, including wolf species in northern Portugal. Our earliest studies were general, but insufficient to help when we found species problems. Now we focus our monitoring efforts on sensitive target species. This presentation focuses on raptors and soaring birds.

Initially, we did not have the opportunity to propose alternative sites; wind development companies would come to us having already decided on a site. Now we get clients who come asking whether a proposed layout is o.k., and we do spatial and risk analysis to answer that question.

Slide #8 illustrates how we select species to study, based on their conservation status and vulnerability to wind farms and their presence (rare / common / very common) on the site. We focus on species that are common and threatened and/or sensitive to collision. For the species selected, we then:

- Analyze nesting locations for breeding species
- Do spatial (horizontal and vertical) maps showing bird activity

Slide #10 shows an example from a proposed wind energy facility in southern Portugal where there is a big population of Bonelli's Eagles. We identified nests and defined distance classes, proposing a 1.5-km minimum distance from nest to nearest turbine. This resulted in a change in turbine layout at the site.

Bird activity data were collected through field point observations, which allow a good cover of the wind farm area and its surroundings. All field information is put into GIS software, allowing us to do both visibility and spatial analysis. Horizontal and vertical use maps were built, and a "Collision Hazard Index" was estimated. This index was determined for all the species occurring in the area and for the species selected by the risk assessment matrix. In slide #12, height is represented by color.

Horizontal use is mapped on a grid on which color is used to show the number of movements observed in each cell. However, this does not give much information about how birds are using the area. Vertical use maps use a similar grid, with color used to represent the number of observations above, within, and below the rotor zone. The horizontal and vertical maps are overlaid to create a collision hazard index for proposed turbine locations.

This index is the basis for proposing that specific proposed turbine positions be re-located.

### ***Case study 1***

One of the first wind energy facilities built in Portugal had no pre-construction assessment. During post-construction monitoring, we found breeding harriers and a lot of movement of species in the northern part of the wind facility. We also found four dead birds around three of the turbines: this represented significant mortality, as there were only a few breeding couples on the site.

### ***Case study 2***

Slide # 18 shows a wind resource area (outlined in green) where a company wants to build a wind energy facility (outlined in orange). We have identified two sensitive species – Common Kestrel, which is commonly killed by turbines, and also Bonelli's Eagle. In this case, however, the collision hazard index showed us that we did not need to propose changes to the proposed turbine locations.

### ***Summary and research needs***

To re-cap, we perform an ecological baseline study for one year, perform risk-analysis to determine target species, and then conduct spatial analysis, identifying nesting sites and mapping major activity areas to produce a three-dimensional collision hazard index.

To improve this work, we need to do research to tell us how much effort is needed, and how big sample sizes need to be for specific species.

## Questions & Discussion

***Do you find that wind developers generally are agreeable to changing turbine locations if you recommend it? If so, is it because there are stringent laws, or are developers more sensitive to ecological concerns in Portugal?***

Marques: One of the main reasons developers are agreeable is that it makes it faster to get a project approved. Projects have to pass an EIA. If the work has been done correctly, it is easier to get the project approved. It also has advantages in avoiding future problems during post-monitoring studies.

***What is the basis for assigning greater risk to bird activity below the rotor zone versus above?***

Marques: We thought it would be more probable for birds flying below the rotor zone to be at greater risk, as they are using the area for behaviors like foraging. Many birds that are flying above the blades are just passing through the area.

***Are the “detailed track” data collected during point observations, or do you use a separate survey for this, and does this include migration seasons?***

Marques: Detailed track data are collected from observation points. It would be difficult to do these tracks during high-traffic migration periods.

***Has post-construction monitoring validated the model’s risk assessment?***

Marques: We are looking at that now, using analysis to see if we have a difference in spatial use, and performing statistical analyses. At this point it is too soon to know.

***Do you have nesting and movement data for multiple years? Do areas of high bird activity change a lot from year to year?***

Marques: We have maps of the same area for some species for three years. With Bonelli’s Eagle, we do not see much variation from year to year. For smaller species like kestrels, we observe much more variation. So this is species-specific.

***Were vertical and horizontal maps created from point count observations? If so, how accurate are the flight height observations?***

Marques: We try to characterize height in just three classes as shown in risk analysis, to reduce the error. In the field we try to have some reference points in the field – e.g. met stations, trees. Not 100% precise.

***How many years of pre-construction surveys are used/needed before making recommendations to move turbines?***

Marques: We are doing only one year of pre-construction surveys now, because in general this is the period that developers spent in developing the wind facility project.

## Session 7. Understanding Current Knowledge of Offshore Wind and Wildlife Issues

**Moderator: [Terry Yonker](#), *Marine Services Diversified***

The NWCC is venturing into a new line of inquiry with this session today. The Planning Committee wrestled with whether to include offshore wind in this meeting. Here are some of the questions we considered:

- Were these issues being addressed elsewhere, possibly by the U.S. Offshore Wind Collaborative or the Great Lakes Wind Collaborative, or are these issues just a subset of issues being addressed by the NWCC Wildlife Working Group?
- Do offshore methods differ from terrestrial methods?
- Are there noteworthy findings from field studies in the Atlantic, Great Lakes, and Gulf of Mexico?
- Is there an adequate knowledge base for endangered species or species of concern at coastal sites?
- Do we have standards and protocols we can agree on for understanding direct, habitat, cumulative and behavior impacts from offshore wind?
- Can we learn from European offshore projects?
- How do regulatory processes differ for offshore versus terrestrial wind energy projects?

We will try to address some of these questions in this session.

DOE has set a goal of 20% of the nation's electricity from wind energy by 2030 – that means 300 GW of new wind capacity in less than two decades, 50 GW of which is expected to be offshore wind. The DOE's new assessment of offshore wind capacity indicates that over 4000 GW of potential exists in U.S. waters, including more than 700 GW of potential wind capacity in the U.S. waters of the Great Lakes. (Total wind energy potential for the Great Lakes is double that if you include Canadian waters.)

I think it is safe to say that a wave of offshore wind development is approaching our shores, and that we are not totally prepared to address the impact of it. We need to take a step back and look at alternatives for addressing offshore issues or we could be quickly overwhelmed.

In many cases, we will have to assess potential offshore impacts remotely. Weather and migration patterns for birds and bats may differ significantly from terrestrial patterns. Nocturnal passerine and shorebird migration along the coasts and across the Great Lakes may not be risk-free, especially when birds encounter turbines offshore during marine weather events.

The impacts of climate change will disproportionately impact the coasts. Habitat issues offshore and along coastal areas likely will differ from terrestrial habitat issues, and may render land-based models ineffective. In many cases – especially in the Great Lakes – we have to recognize that we have very little data or understanding, and that we must cautiously “bootstrap” our way up from the lower left-hand quadrant of Starfield's virtual graph.

I have spent several years observing bird migration on the Great Lakes. During early spring migration in the middle of Lake Erie, the Straits of Mackinaw, and on Lake Superior, I have witnessed passerines by the thousands using ice as stopover and foraging habitat. Anecdotal evidence abounds of large numbers of nocturnal migrants colliding with offshore lighthouses and working ships in the fall. We have seen scavenging of passerines by gulls along the southern shores of Lake Erie and Lake Ontario when buffeting winds drew the exhausted birds down to the water's surface.

There is much uncertainty about the efficacy and environmental impacts of offshore wind power, and that uncertainty is reflected in the strong opposition from many coastal communities. Indeed, uncertainty about wildlife impacts provides ammunition to offshore wind opponents whose principal concern is view-shed aesthetics rather than birds, bats, and aquatic species. We must be able to separate myth from reality and we must do it quickly if wind energy is to be successfully deployed offshore.

### ***Danish Experiences with Offshore Wind Farms and Wildlife: Results of a Strategic Environmental Monitoring Program***

[Jesper Kyed Larsen](#), Vattenfall Wind Power

[Link to Presentation](#)

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**Research objectives:** Presentation summarize wildlife impacts of offshore wind energy facilities in Denmark, conveying some major lessons learned with regard to the management, setup and design of offshore wind and wildlife interaction studies.

**Key terms:** demonstration projects, Denmark, lessons learned, offshore wind farms, strategic environmental research

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Wildlife impacts of offshore wind energy facilities have been studied in Denmark since 1991, when the first small-scale offshore facility was built. Since then the number of wind energy facilities has increased to 11, including three large-scale wind energy facilities, currently totaling 665 MW of installed capacity. (Slide #4 shows the location of operating and planned offshore facilities.) The first large-scale offshore wind demonstration projects were built eight years ago at Horns Rev (80 2-MW turbines) and Nysted (72 2.3-MW turbines). Uncertainty about impacts led to the establishment of an extensive monitoring and research program around these projects.

#### ***The Environmental Monitoring Program***

A comprehensive environmental monitoring program was initiated in 2000, connected to the demonstration wind energy facilities Horns Rev and Nysted, funded at a level of \$15 million from Danish electricity consumers (through a public service obligation). The program included studies on benthic fauna, fish, marine mammals and birds, as well as socioeconomics. In general, these studies used the BACI approach, but also required that several novel techniques be developed. The original program was finalized in 2006, and the results presented in the form of reports and a book. A follow-up program was funded to clarify outstanding issues of specific relevance to the planned future offshore wind energy

facility development in Danish waters. This program includes studies on fish, marine mammals and seabirds, most of which are ongoing, but there are some new results that can be presented as well.

The original and the follow-up program are both coordinated by a steering group (The Environmental Group), consisting of representatives from the Danish Energy Agency, the Danish Nature Agency, and the operators of the two wind energy facilities, Vattenfall and DONG Energy. The total budget is 84 million DKK (equivalent to about \$15 million). The steering group is assisted by an advisory panel of recognized international experts within a range of marine ecology fields. In addition, during the original program, the steering group was in continuous dialogue with a “green group” of key NGOs.

### ***Major findings***

#### Benthic flora and fauna

- Biomass and species diversity increased on turbine positions, with a minor increase in overall biomass over the project area.
- Native benthic communities are not affected at the project scale, but local effects were found around turbines at Nysted.
- Flora and fauna were affected close to the cable trench, but were recovering after two years (Nysted).

#### Fish

- Fish abundance and diversity was not found to differ markedly between project and reference areas.
- No marked artificial reef effect demonstrated.
- No indications of effects on sand eel habitat or abundance (Horns Rev).
- No unambiguous effect of electromagnetic fields on fish behavior or migration (Nysted).
- Long-term effects (7 years post-construction) on fish communities are being studied at Horns Rev.

#### Mammals

We looked at harbor seals and harbor porpoise, both during construction and operation phases.

- Seals appeared to avoid the area during pile driving/construction and pile driving also had a substantial but short-lived (4-23 hours) effect on porpoise activity
- No general change in seal numbers or behavior at sea or on land could be linked to the operation of the wind energy facilities
- No effect on porpoise numbers/activity during operation at Horns Rev; reduced activity at Nysted, but recovering
- Harbor porpoise studies on efficiency of deterring devices (seal scarers) and cumulative effects are ongoing.

#### Birds

- Numbers of feeding and resting birds within and around the project areas were markedly reduced for some species (red-throated diver, long-tailed duck), while others seemed not to be affected.
- Flying water birds generally avoided the facilities, but some more than others.
- Migrating common eiders demonstrate low collision risk; based on modeling/visual observation, fewer than 50 of 230,000 eiders were likely to collide.

- Deflection behavior results in extended flight distances, but is found unlikely to have significant energetic consequences for migrating common eiders.
- Studies on habitat loss and cumulative effects for divers and sea ducks are ongoing.

### ***Lessons learned***

- Large-scale offshore wind energy facilities can be constructed and operated with little impact on the environment; spatial planning is important, however, to ensure an environmental sustainable development.
- Studying effects of wind energy facilities in the marine environment is notoriously difficult; it is logistically very challenging and hard to control confounding factors.
- Spatial scale of effects varies between construction and operation and among fauna groups; during operation, for benthic fauna, fish, marine mammals and some bird species effects seemed generally to occur at a turbine rather than a facility scale.
- It may take some years for final effects to show due effects to succession in benthic communities and habituation responses by water birds (e.g. common scoters, Horns Rev).

These wind energy facilities were not sited with the aim of avoiding impacts all together, but rather with a view to provide an opportunity for building up knowledge. It has proven useful to learn by doing; the demonstration projects and research program at Nysted and Horns Rev have greatly helped to inform planning and impact assessment for subsequent offshore wind energy facilities, as well as focusing monitoring requirements. This approach does require some bravery, and also an allocation of sufficient funds to ensure solid studies and applicable results.

### ***Publications and further information***

Popular summaries of 1999-2006 research results:

- [Offshore Wind Farms and the Environment. Danish Experiences from Horns Rev and Nysted \(booklet\)](#)
- [Danish Offshore Wind – Key environmental issues \(book\)](#)

Scientific reports (1999- ):

- [http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/offshore-Wind-Power/Environmental-impacts/env.reports\\_for\\_specific\\_projects/Sider/Forside.aspx](http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/offshore-Wind-Power/Environmental-impacts/env.reports_for_specific_projects/Sider/Forside.aspx)

Ongoing EMP studies:

- [http://www.ens.dk/EN-US/SUPPLY/RENEWABLE-ENERGY/WINDPOWER/OFFSHORE-WIND-POWER/ENVIRONMENTAL-IMPACTS/FOLLOW\\_UP\\_ENVIRONMENTAL\\_PROGRAM/Sider/Forside.aspx](http://www.ens.dk/EN-US/SUPPLY/RENEWABLE-ENERGY/WINDPOWER/OFFSHORE-WIND-POWER/ENVIRONMENTAL-IMPACTS/FOLLOW_UP_ENVIRONMENTAL_PROGRAM/Sider/Forside.aspx)

Offshore wind in Denmark:

- <http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/offshore-Wind-Power/Sider/Forside.aspx>

Offshore wind environmental impact studies:

- Tunø Knob demonstration project (1995, 10 500kW), sea duck studies 1994-1998 (common eider)\*

- Horns Rev 1 (2002, 80 2MW) and Nysted (2003, 72 2.3MW) large-scale wind farm demonstration project – The Environmental Monitoring Programme, 1999-ongoing ([range of issues](#))
- German studies [post-construction studies](#) 2005-2006 (birds, harbor porpoise) at Horns Rev 1 and Nysted
- Horns Rev 2 (2009, 91 2.3MW) monitoring programme – [construction phase studies](#) on harbor porpoise 2008
- The Habitat Modelling Project (further field studies at Nysted and modelling of effects)\*

\* Contact <mailto:jesperkyed.larsen@vattenfall.com> for further information and publications.

## Questions & Discussion

### ***How do you calculate mortality of offshore wind energy facilities? Were you able to directly monitor fatalities or did you primarily use modeling?***

Larsen: At Nysted for migrating waterfowl, a stochastic collision risk model was developed with input from radar and visual observations. As a supplement an automated video camera surveillance system monitored the rotor swept area off a single turbine. The video system recorded a single potential collision (a small passerine/bat) during 2400 hours of operation, corroborating the low number of collisions predicted by the model.

### ***With a growing industry, how are cumulative impacts of offshore wind on marine mammals, birds, fish, etc. being considered in Denmark?***

Larsen: The program have so far first of all focused on establishing effects of individual wind energy facilities, but recently follow-up studies have been initiated (for harbor porpoise and divers) with the aim of addressing the potential cumulative effects of an increasing number of wind energy facilities together with other human uses of the offshore environment.

### ***Do large cetaceans migrate through or breed in waters off Denmark?***

Larsen: Large cetaceans are rare in Danish waters. The harbor porpoise is the only abundant cetacean species.

### ***Were effects on the fishing industry measured or assessed? If so, were there issues? How were they resolved or mitigated?***

Larsen: The impact on fisheries interests in the development areas were assessed based on existing fisheries statistics and information on area use. An economical compensation was negotiated.

### ***Were any studies conducted on the production of sound and vibration by operating turbines, and on their impacts to biological resources?***

Larsen: Underwater sound emissions were measured at Horns Rev during operation. Potential effects of sounds/vibration on marine organism was not specifically studied, however, there were no indications that benthic fauna or fish were avoiding the proximity of the turbines to any larger extent.

***Were any marine invasive/exotic species established on the substrate provided by the turbine bases? If yes, what were they?***

Larsen: Yes, the midge *Telmatogeton japonicus* and the amphipod *Caprella mutica*.

***How is an off-shore turbine constructed? How far off-shore are they?***

Larsen: The two mentioned facilities is located 10-15 km from the coast at 5-15 m of water. In the book Key Environmental Issues (link on slide #10) you can find some more information on the construction of the facilities.

***For the two sites studied, how many turbines are there at each site, and how are they arrayed?***

Larsen: See slide #12 – Horns Rev has 80 2-MW Vestas V80 on monopole foundations, 14 km from the coast. Nysted has 72 2.3-MW Bonus turbines on gravity-based foundations at a distance of 10 km from the coast. Both are arrayed in parallel rows, making a square or rectangular configuration.

***You mentioned that the effect on flight energetics of migrating birds avoiding terminals is minimal. Did you study this in detail (quantitatively), or was this more of an anecdotal conclusion?***

Larsen: The additional cost of the deflection of common eider flight paths observed at Nysted was estimated using an avian energetic model – see: Masden et al. 2009.<sup>5</sup>

***Did your summary statement that “flying birds generally avoided turbines” include song bird data?***

Larsen: This statement referred to water birds, as they were the primary focus of the bird migration studies.

***What proportion of Denmark’s energy use is provided by wind? How much of that comes from off-shore developments?***

Larsen: Currently wind energy provides about 3% of the Danish energy consumption and 20% of the electricity consumption. Of this about one quarter comes from offshore wind.

***What is the population context of local reduction of harbor seal numbers – are harbor seals numbers robust, increasing, or declining?***

Larsen: Harbor porpoise numbers are generally thought to be declining in Danish waters.

***Was hydrology studied before and after wind farm? Transport of nutrients and invertebrate larvae?***

Larsen: Hydrology was studied prior to development, and effects on hydrography and sediment transport assessed to be insignificant.

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<sup>5</sup> Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W., Bullman, R., and Desholm, M. 2009. Barriers to movement: impacts of wind farms on migrating birds. – ICES Journal of Marine Science, 66: 746–753

## ***Challenges and Solutions for Using Radar at Offshore Wind Energy Developments***

[Jenny Davenport](#), DeTect, Inc.

(Co-authors: T. Adam Kelly, Tim West, Andreas Smith, DeTect, Inc.)

[Link to Presentation](#)

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**Research objectives:** Listing current challenges of using radar for bird and bat studies at offshore wind energy developments; exploring possible solutions while considering the pros and cons of each; outlining important considerations when developing offshore radar studies.

**Key terms:** avian survey, offshore, radar, wave clutter

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Offshore wind energy development presents new challenges in assessing potential impacts to birds and bats from wind turbines. Radar has become an important tool for assessing bird and bat impacts at land-based wind energy sites, e.g., to determine pre-construction bird and bat activity, as well as post-construction monitoring which can be used to compare with pre-construction activity and habitat use. A new application uses radar to forecast high-risk collision events (Erickson, p.106). Radar promises to play an even greater role at offshore sites, given both the lack of knowledge about bird and bat activity offshore and the increased difficulty in obtaining data from offshore sites that are often remote, difficult to access, and unable to support traditional land-based assessment methods.

However, there are several issues that continue to hinder the potential usefulness of these radars at wind energy sites, with offshore sites providing a particular suite of challenges. These include: 1) wave clutter from wave action, 2) detecting and tracking targets on or immediately above the water's surface, 3) interference from other radars used by boats for navigation; and 4) site remoteness and weather conditions that affect radar performance.

This presentation provides an overview of these challenges and discusses current and developing solutions to address them. We also outline important considerations when developing an offshore radar study: e.g., study time periods, pros and cons of different radar systems, and availability of power sources and support structures.

### ***Wave clutter***

Wave surfaces are dynamic and strongly reflect radar energy, creating clutter in the radar image. Wave clutter can create false targets or prevent target detection by swamping the display. It can also decrease the sampled area, and complicate temporal and spatial comparisons when the sampled area changes. Wave clutter also makes traditional clutter maps ineffective and tracking algorithms less effective.

Solutions to the wave clutter problem include vertically scanning radar, "radar fences", and static clutter maps.

- *Vertical radar* minimizes the water surface area, thereby avoiding wave clutter. It also collects altitude data and better count data for flying targets. The disadvantage of vertical scanning radar is that it does not collect directional data.

- Radar fences absorb radar energy in the lower portion of the beam, creating an artificial horizon above the surface of the water that allows consistent detection of targets in the upper portion of the beam. For land-based radar, a metal fence or vegetation can be used to create a radar fence. Near or off-shore radar can use a tube or plate with Radar Absorbent Material (RAM). The disadvantage of radar fences is that they can decrease the sampled area, and they eliminate targets directly on or just above the surface of the water.
- Clutter maps are of two kinds. Traditional clutter maps use previous scans to quantify and remove ground clutter; the challenge is that dynamic waves do not allow for consistent clutter quantification. Static clutter maps use worst-case sea states to quantify and remove wave clutter. This creates degraded but *consistent* target detection in all sea states.

These techniques can be used in conjunction with each other to reduce wave clutter.

### ***Targets on or just above water***

Many sea birds rest or forage directly on the water surface, or fly very close over the surface. It is important to document changes in movement patterns or habitat use of these birds, but wave clutter interferes with detection of these types of targets. Possible solutions include scan-to-scan integration correlation, frequency diversity processing, and Doppler processing.

- Scan-to-scan integration correlation is a technique used to detect stationary or slow-moving targets on the water's surface. It requires rapid antenna rotation (40-120 rpm versus 18-28 rpm), relying on integration of many previous radar scans to smooth away wave clutter and impulse noise. Stationary targets stand out clearly, and slow-moving targets show up as "slug-tracks." (Slide #13 shows an example.)
- Frequency diversity processing involves alternation of two different frequencies from pulse to pulse, followed by integration of signal strength. Wave clutter has a greater radar cross section variation and averages a lower signal return than targets, enabling removal when signal strengths are integrated. The disadvantage of this method is that it requires two transmitters and synchronized receivers, adding significant cost.
- Doppler processing relies on Doppler radars which start and stop transmission at a known wave phase to allow accurate Doppler shift measurements. The resulting velocity differences can be used with tracking algorithms to separate small, weak bird targets from a background of stronger wave clutter.

### ***Interference from other radars***

Ships use marine radar for navigation, and radar using the same frequency band and active in close proximity can cause interference. One solution is to use the longer wavelength (10 cm) s-band radar (ships typically use 3-cm x-band), which also has the advantage that it can be used in low-visibility rain or precipitating fog conditions. Another solution is to use Constant False Alarm Rate (CFAR) in conjunction with interference rejection algorithms.

CFAR shortens interference radials to a single point. These points could mistakenly be incorporated into tracking algorithms, which necessitates using a second method (interference rejection algorithms) to get rid of the residual points. (See slide #18 for an example of a radar image with and without CFAR.) While it is possible that residual points might be falsely correlated with target tracks, the combination of interference rejection algorithms and care in correlating plots to target tracks minimizes this problem.

### ***Remote and harsh site conditions***

Offshore site challenges include limited access, power sources, and structures for radar equipment. Environmental conditions can be harsh, with high humidity, winds, sea salt, and extreme temperatures. Rain, precipitating fog and sea spray can also inhibit target detection by x-band radars.

Solutions for power sources include batteries, fuel generators, solar panels, and even small wind generators – consider the limiting factors of each when looking at the resources of a particular site as well as the possibility of using several power sources in combination. Support structures for radar must be relatively close to the site in order to collect representative data. A monopole met tower, research platform, or jack-up barge may be used. If radar is mounted on a boat deck, a radar stabilizing platform is required. Automatic radar systems with full remote control and data access have many advantages over manual systems due to site remoteness and access difficulties. Fiber optic (often only available post-construction), point-to-point wireless, cellular, or even satellite links can all provide avenues for remote control and access of data.

Equipment protection is another important consideration when implementing a radar study, and environmentally controlled enclosures will be needed for computers and ancillary electronics. Finally, consider the frequency band of your radar. X-band radars are commonly used for avian radar studies, but the longer-wavelength s-band radar is able to collect data in critical low visibility conditions such as rain and precipitating fog. All of these are important considerations when designing a radar study offshore.

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## Questions & Discussion

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***Does horizontal s-band produce less wave clutter than horizontal x-band, and will you still recommend use of a “radar fence” for s-band too?***

Davenport: You get wave clutter with both s- and x-band radar. It tends to be worse with x-band radar, but it depends on the surface of the waves. Therefore, radar fences are useful when using s-band, as well as x-band radar, in reducing or eliminating wave clutter.

***Can you speak to efficacy of mounting radar units on moving or stationary vessels? Can shore-based radar units be used for offshore target detection? To what extent? To what distance?***

Davenport: If you are using radar on non-stationary objects such as a boat, you will need some sort of stabilizing platform to get accurate data. Shore-based radar (on the coast or on islands, looking out over water) can be used to detect targets at offshore sites that are relatively close, generally within distances of 1-4 nautical miles (depending on radar frequency band and size of target you’re interested in) in order to detect bird and bat-sized targets within the site.

***Are those “interference rejectors” part of the radar unit or are you using an added algorithm?***

Davenport: The Interference Rejection Algorithms have been added to our MERLIN avian radar software we use for detecting and tracking targets. It can be used during post-processing, but in our new Solid State radars they clean up the data in real-time, so cleaned data is recorded and no post-processing is needed to remove this type of interference

***How can radar reduce direct and indirect interference from turbines (e.g. moving rotor blades and “ghost” tracks due to the turbine sidelobes)?***

Davenport: You can use clutter mapping to mask out the rotor blade tips; this prevents false tracking of moving blade tips. Doppler can also be used to reduce the magnitude of the stationary parts of the turbine structure. Right now the most common method for dealing with the turbine is to mask it out.

***Can you expand on what you mean by “better count” data in vertical?***

Davenport: Vertical radar data provides better count data, or target passage rates, than horizontal radar for several reasons. Compared to horizontal radar, vertical radar samples more of the airspace above the radar, samples a more uniform volume, and is less susceptible to ground or wave clutter so targets are detected against mostly clear air, all of which allows detection of more of the targets present and therefore gives more accurate target counts.

***Are there any sea birds as large on radar as metal buoys?***

Davenport: The size of the buoys used during the Scan-to-Scan Integration Correlation test were meant to simulate a human overboard (head, neck, and shoulders of a person in water). Although not intentionally part of the test, birds were also present and showed up as the “slug tracks” you can see on the image. If those birds had been stationary instead of moving slowly, they would have appeared even brighter. So we know this technique can detect both stationary and slow-moving birds on the surface of the water.

***With s-band, how does the probability of detection change with distance from the radar unit?***

Davenport: Similar to x-band radar, the probability of detection decreases with distance from the radar unit, and with target size.

***Has DeTect published any of the avian radar studies in scientific journals?***

Davenport: The information in this presentation has been published (Kelly, West, and Davenport 2009<sup>6</sup>), but none of our avian radar studies have been published yet in scientific journals.

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<sup>6</sup> Kelly, T.A., T.E. West, and J.K Davenport. 2009. Challenges and solutions of remote sensing at offshore wind energy developments. *Marine Pollution Bulletin*. 58:1599-1604.

## ***Evaluating Piping Plover and Red Knot Use of the Atlantic Outer Continental Shelf (AOCS) During Migration Using the Avian Knowledge Network***

[Greg Forcey](#), Pandion Systems, Inc.

(Co-authors: Caleb Gordon, Joanna Burger and Larry Niles, Pandion Systems)

[Link to Presentation](#)

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**Research objectives:** To evaluate whether migrant Red Knots and Piping Plovers migrate across offshore waters where future wind development could occur; to use terrestrial (coastal) data to try to answer a marine question.

**Hypothesis:** Coast-hugging migrants take short-cuts over water during migration to avoid longer circuitous routes around large bays and inlets.

**Key terms:** exposure, migration, Piping Plover, Red Knot, shortcut hypothesis

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We began our attempt to understand Piping Plover and Red Knot use of the Atlantic Outer Continental Shelf (AOCS) by gathering all the existing pelagic geospatial data from Cornell's Avian Knowledge Network (AKN). The AKN is a geospatial database managed by Cornell Lab for Ornithology, drawing on data from multiple sources, with the goal of understanding the patterns and dynamics of bird populations across the Western Hemisphere.

There is not very much pelagic data available for Piping Plovers and Red Knots. But there was a lot of coastal data for these species. What can coastal data teach us?

Slide #5 illustrates the "short-cut" hypothesis, i.e., that coastal migrants actually take short-cuts over water to avoid more circuitous "coast-hugging" routes. Ovals on the slide represent portions of the route where birds are crossing an expanse of water. Slide #6 presents an alternative hypothesis, which is that birds neither hug the coast nor follow the coast-line with occasional short-cuts over water, but instead maintain a more direct non-coastal north-south pattern. If this is the case, we would expect to see more diffuse exposure than we would in either the coast-hugging or short-cut cases.

In particular, if birds are migrating up the coast, we would expect to see birds concentrated along the coast at stopover locations, and also would expect to see a pulse of birds moving up the coast during spring migration. If the migration is non-coastal, we would not expect to be able to follow a pulse up the coast, but would instead see birds appearing at their breeding grounds in a discontinuous fashion. (See slide #8.)

### ***Geospatial analysis***

To test this hypothesis, we did a geospatial analysis using 83,407 sampling bouts from the AKN database. After quality control, we were left with 48,351 sampling bouts (58%). We then established a 5-km grid within the study area (from the Delmarva Peninsula up to the southernmost tip of Maine coast – see slide #9). We then summed bird abundance within each cell, including only cells with five or more sampling bouts or positive observations. We performed separate analyses for Piping Plovers and Red

Knots for each migratory season. Sampling units were delineated along coastal areas that allowed us to quantify relative bird abundance in these areas. For Red Knots, we did a seasonal analysis; for Piping Plovers, we analyzed the data on a monthly basis.

Slide #11 shows a week-to-week time-lapse video of Piping Plover movements up the coast. Blue is areas sampled, no birds observed; red is highest level of abundance. What we see here is that there are no migratory pulses either during the spring or the fall migrations; in the spring, birds just show up on the breeding grounds.

Slide #13 gives a more aggregated picture for Piping Plovers. In the month of June, we assume that all birds are on their breeding grounds, and we use this to compare with April (spring) migration where we do not see any concentrations of birds along the coast. We see a similar picture in fall. Slide #15 graphs the data with frequency histograms for each month (x-axis is number of birds seen, y-axis is number of times). We do see a few high numbers of counts in spring and fall, but we also see that during the breeding season. Slide #16 displays the same information in a table. The third column, which gives the mean number of birds observed per sampling bout, is the most informative; we don't see more plovers during the spring and fall migration periods than we do during the summer; in fact, the highest number of observations is in July.

For Red Knots, we see different spring and fall routes. During spring they show up in the Delaware Bay in great numbers and they are relatively absent elsewhere. In the fall, Massachusetts (Cape Cod) is the hot spot, and the birds are relatively uncommon elsewhere.

### ***Implications for exposure***

For Red Knots, the areas north and south of Delaware Bay appear to be hotspots in the spring, north and south of Cape Cod, Massachusetts are hotspots in the fall.

We also have data from another study of Red Knots. We actually captured three birds and put geolocators on them. Slides 20-21 show their migration routes from the Delaware Bay (spring 2009) up to the Arctic Circle breeding grounds, and then coming across Massachusetts Bay in the fall on its way down to South America (Niles et al. *in press*). The other birds also took different routes in the spring than they used in the fall.

### ***Conclusions***

Our results suggest that both Piping Plovers and Red Knots use offshore shortcuts during their spring and fall migrations. We do suspect that some birds are following the coastline, but most of them do not seem to be doing this. Offshore wind siting decisions should therefore consider that these shortcut areas represent regions where Piping Plovers and Red Knots could be exposed to offshore wind turbines during migration. Note that we are only talking about exposure here, not risk. Further research on flight height and behavioral avoidance is necessary in order to determine the degree to which this increased exposure translates into increased collision risk in the AOCS.

Slide #24 summarizes what we know about where these birds are exposed. The figure on the left shows numbers from the USGS Annual Winter Piping Plover Census. It shows that most Piping Plovers are traveling over land (from the Gulf of Mexico), but there are other populations coming from Florida and the Caribbean, and we suspect those are going to be most exposed over the ocean. It is possible that these birds are migrating coastally but non-stop, but given the tendency of those birds to occur on

islands, they are obviously flying over water to get to those islands, which gives evidence for non-coastal migration.

## Questions & Discussion

***With the geo-locators on the Red knot, were you able to draw any conclusions regarding behavior during stop-over in Massachusetts and Delaware Bays?***

Forcey: Larry Niles did this field research – would direct this question to him.

***What is possibility of missing data? For example, both species Piping Plover and Red Knot) are observed regularly near Tampa, Florida.***

Forcey: Birds could be migrating non-stop along the coast. In that case, they would not likely be recorded as well as if they stop over. But we see them on islands, so we know that they do fly over water.

***I work with Piping Plovers in NJ and we do see migratory concentrations in the fall. Will you vet your results with the Atlantic Coast Piping Plover recover team before making final conclusions? Will you also be conducting field observations to confirm your hypothesis?***

Forcey: Yes, our report will be reviewed by Anne Hecht who is on the team. Field observations are what we used for this study so I'm not sure of the value of conducting additional observations given we would not be able to collect those data at the same scale as the data in the Avian Knowledge Network. That being said, we are always looking for new datasets to use in our analysis and if new datasets became available we would use them.

## Maine Offshore Bird and Bat Pilot Project

[Steve Pelletier](#), Stantec Consulting, Inc.

(Co-authors: George Kendrick, Trevor Peterson, Adam Gravel, Stantec Consulting)

[Link to Presentation](#)

**Research objectives:** The following research objectives were defined:

1. Initiate the first quantitative offshore regional bat survey.
2. Initiate the first offshore avian (x-band) radar study in Gulf of Maine.
3. Assess effectiveness of equipment and methods in marine environment.
4. Compare methodologies and results of prior (138 acoustic bat; 109 radar) land-based seasonal surveys with off- and near-shore surveys.
5. Compare radar survey results with four concurrent onshore (interior Maine) studies.
6. Assess viability of regional fall migration data trends.
7. Obtain baseline data on day/night avian migration characteristics.
8. Refine protocols and sites for expanded comprehensive study.

**Hypothesis:** Previously identified seasonal trends and patterns of (fall) avian and bat migration in terrestrial onshore regions are influenced by seasonal offshore conditions.

**Key terms:** acoustic, bat, Maine, offshore, radar

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Information about the offshore movements of birds and bats is very limited. At the same time challenges associated with gathering ecological data in the offshore are difficult, and often prohibitively expensive and dangerous. We have collaborated with federal and numerous state agencies in developing viable avian/bat migration survey methods at proposed wind energy sites since 1994, and as of December 2009, have conducted a total of 138 acoustic bat survey seasons and 109 radar surveys at more than 85 onshore wind energy facilities. Much of the site to site onshore (terrestrial) data gathered to date has been found to be relatively consistent in terms of seasonal activity, passage rates, and flight heights. But do these same patterns hold true offshore?

To learn more about what animals are flying, at what heights, in what seasons, a regional pilot project was conducted in the late summer and fall of 2009 off the Maine coastline. Our primary focus was on assessing the presence/absence, and seasonal movements of various bat species with the aid of strategically placed acoustic bat (AnaBat) detectors. This effort was to be the first offshore regional survey of bat migration. We also hoped to test the viability of our terrestrial-based methodologies and equipment in the offshore environment, as well as our remote access capabilities.

A secondary purpose of the pilot project was to assess nocturnal passerine and daytime movements of shorebirds, water fowl, and pelagic seabirds with the use of marine (x-band) radar. Combined with the acoustic bat survey effort, we hoped to evaluate regional trends, to compare our offshore results with other similar, ongoing, onshore Maine studies being conducted during the same time period, and establish a baseline and context for further data collection efforts.

#### ***Pilot site selection***

We selected 12 sites distributed along an approximately 125-mile stretch of Maine coast (slide #6), extending from Half-Way Rock in Casco Bay, down easterly beyond Mt. Desert Rock off Acadia National Park, to Petit Manan Island located off Milbridge, south of the Canadian border. Two sites were situated on the mainland coastline and ten were on islands, up to 20 miles offshore. Acoustic detector systems were set up at each of the 12 sites while X-band radars were positioned at Schoodic Point and Great Duck Island to allow a coastline to island transect. Due to the nature of the study sites, acoustic detectors were mounted high on lighthouses at 9 sites, while detectors at 3 others sites were able to be positioned away from any potential influence of the lighthouse light. Access onto many of the remote islands was highly restricted, and could only occur under appropriate weather conditions and by transferring equipment and personnel into smaller boats.

#### ***Acoustic bat survey results***

Acoustic bat data from ten island and two coastal sites were collected between July 28 and November 15, 2009, with additional data from at least 2 island sites continuing into winter and early spring 2010. Over 14,500 time-stamped bat call files were identified over the course of 858 detector-nights of data collection. Overall success rates were high with an average of 72 nights of data collection/site.

Bats were detected at all 12 survey sites, with bat activity detected as late as November 10 at least at one site. Also important was the fact 2 migratory bat species, silver-haired (*Lasionycteris noctivagans*)

and eastern red (*Lasiurus borealis*) were detected at every site, with the third migratory bat, hoary (HB), detected at 11 of 12 sites. There was a high nightly call volume fluctuation, with activity peaks (e.g., Sept. 5 and Oct. 5-8) observed at multiple survey locations (slide #15), and a wide variation of species composition by site (slide #16). There are no clear patterns that emerge from this data – no one mix of species dominating individual sites.

Acoustic survey results by site, guild, and species as applicable, guild are presented (slide #17). *Myotis* species, silver-haired, hoary, and eastern red bats are the most commonly detected species. Big brown and red bats are locally abundant at certain sites; tri-colored bats were notably absent at all sites during the entire survey period.

We also assessed seasonal activity patterns to determine if there were migratory activity peaks for different species. Both hoary and silver-haired bat activity peaked between early August and mid-October; silver-haired bat activity appeared more tightly concentrated than hoary bat activity. In terms of spatial distribution, hoary and silver-haired bats were detected at seven and eight sites (respectively) of the 11 sites monitored on Sept. 5. For most of the survey period, these species were detected at 0-1 site on any given night.

Another way to get a sense of the variety in the data is to look at examples from two sites. Seguin Island was an anomaly in terms of the large number of calls recorded.

Site location	Mt. Desert Rock	Seguin Island
Description	~ 2-acre island; 20+ miles from mainland; Detector deployed on lighthouse tower	64-acre island; 2.5 miles from mainland; lighthouse
# nights of data	75 nights (8/18-10/31)	79 nights (8/25-11/11)
Total # bat calls	349	8,476
Species detected	hoary, silver-haired, eastern red, and <i>Myotis</i> species	hoary, silver-haired, eastern red, and <i>Myotis</i> species
% of nights activity detected	20%	57%
Max # nightly call sequences recorded	104	1,337

A reduced (acoustic bat only) survey effort is being conducted in 2010 at 1 coastline and 8 island sites, and includes a southerly expansion to Appledore Island off the coast of New Hampshire. Data from 2010 will be compared with 2009 to better understand year to year variations.

### **Radar data**

A reduced effort to obtain radar observations of nocturnal (e.g., passerine) migration and daytime seabird movement patterns was also undertaken. A complete effort was however limited by passage of 2 hurricanes and island access issues at Great Duck Island. Further, preliminary data indicated lower passage rate and flight height levels than previously observed at other sites and as such suggests prudence when evaluating the results of the pilot effort. Between August 18 and the end of October 2009 we collected a total of 29 nights of data from Schoodic Point, and three nights of data from Great Duck Island. Radar target passage rates averaged 64 targets/km/hour at Schoodic varying from a low of 5 t/km/hr (Sept. 23) to a high of 546 t/km/hr (August 19). This was low compared to what has been

previously observed at terrestrial sites throughout the northeast, and low when compared to similar, concurrent studies at 4 Maine inland sites during fall 2009 (slide #12). The timing of passage rates also differed from what has been typically observed on land. Offshore passage rates were typically highest between six and nine hours after sunset, whereas terrestrial hourly passage rates tend to peak three to four hours after sunset.

The mean flight height of all targets over the course of the season was 242 m (794 ft) above ground level. About a fifth (21%) of targets was observed to fly below 125 m – the typical height of a wind turbine; this percentage varied nightly from 0% to 53%. In radar survey results to date (slide #13), we are seeing lower flight heights at the coastline than what is observed at interior inland sites.

## Questions & Discussion

***Regarding your radar images of flight heights – few found within the future rotor swept area; how many inclement weather events influenced this data set? Were you using only x-band radar which does not effectively detect “targets” in the rain?***

Pelletier: We used a 10 kW X-band (3-cm) radar; we did not operate during inclement weather, although data analyses included nights with intermittent rains.

***What was overall average activity for bats (# passes/detector-night)?***

Pelletier: The average activity level varied widely between sites with total calls ranging from 27 at Monhegan Island to 8476 at nearby Sequin Island. Further, the results should be interpreted with caution as the number of passes can't be distinguished by individual bats (e.g., is it a single bat passing many times or many bats). Finally, activity levels varied greatly between nights during the survey period. Further study is required to assess levels of bat activity at individual sites and to then better understand offshore activity patterns.

***What happens to bats or birds that collide with turbines – how would you detect fatalities?***

Pelletier: This issue is already a big concern at terrestrial facilities in which hours can literally be spent walking transects under individual turbines. Obviously offshore post-construction monitoring offers an even bigger challenge. Mounting nets and other types of monitoring devices are impractical for a host of reasons efforts – not only expensive but also a potential impact source by themselves. Post construction studies in Denmark and Germany are making some headway with turbine mounted infrared cameras – with limited success, and likely offer the most practicable option.

***Collecting data on islands isn't quite “offshore” – what inferences can you make about what bats are doing out over the water, far from points of land where they might stop over or even be resident?***

Pelletier: I agree there may be some bias. However, several of these islands are isolated and only a couple of acres of barren rock with a lighthouse, located 15 to 20+ miles offshore. Large portions of these islands are regularly swept over by waves. The islands themselves are well beyond areas in which there is already active interest in locating offshore wind farms. Boats and buoys offer alternatives but it's important to remember data from those points is only a few feet off the surface of the water. I'd also add that construction of turbines will also offer a point of potential attraction to migrating and foraging bats as already observed in certain offshore studies off the coast of Europe.

***There are a lot of reports we got today were about birds and bats, question for the panel, what are your thoughts about fish and aquatic species and impacts?***

Pelletier: A good question and likely dependent on the scale of the project and specific benthic and pelagic conditions of a particular site. It's an important concern because many of the seasonal seabird and shore bird movements are in response to local fish and aquatic resources.

***Do you think that detecting migratory bats at 8 out of 10 offshore sites on one night suggests a large-scale migration event along or across the coast?***

Pelletier: No – this is a single fall season pilot effort that focused on a number of varying objectives. However the data was compatible with historic offshore observations and generally in line – both in terms of timing and species – with larger regional observations within the northeastern region. Further study effort would help better understand whether – or to what extent – any true patterns exist in the offshore.

***What type of bat detector was used in your study?***

Pelletier: Paired AnaBat II echolocation detectors were deployed at each site.

## ***Bat Activity in the Vicinity of Proposed Wind Facilities along the Mid-Atlantic Coast***

[Angela Sjollema](#),

University of Maryland Center for Environmental Studies and Frostburg State University

(Co-authors: Dr. J. Edward Gates, University of Maryland CES; Dr. John Sherwell, Maryland Dept. of Natural Resources)

[Link to Presentation](#)

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**Research objectives:** We defined the following research objectives.

1. Determine if migration pathways exist near and offshore on the Mid-Atlantic Coast
2. Assess coastal and offshore bat migration in the following ways:
  - a. Identify which species are active in these areas
  - b. Determine whether there is seasonality to the activity
  - c. Determine if there is a gradient to activity depending on distance from shore;
3. Determine how weather affects bat activity and migration, including wind speed, barometric pressure, and air temperature.

**Hypotheses:** We hypothesized that:

1. There is no substantial bat activity offshore or near shore
2. Species diversity and richness will be similar onshore and offshore
3. There is no difference between spring and fall migratory activity, nor is there a difference based on offshore or onshore locations
4. Bat migration and activity are not affected by weather variables

Many bat fatalities are found below turbines on land – and in particular a lot of migratory bat species are found during fall migration. The mid-Atlantic region is seeing proposals for offshore wind energy facilities 10-15 miles off the coast; bats have been observed offshore in these areas since the 1900s. Because it will be difficult to do post-construction fatality monitoring once offshore projects are constructed and operating, it is important to learn about near and offshore migration pathways before wind energy facilities are permitted and constructed.

The objectives of this study were to determine if migration pathways exist near and offshore along the mid-Atlantic coast; to assess coastal and offshore bat migration in terms of species, seasonality, and gradient; and to determine how weather variables affect near- and offshore bat activity and migration. Our study area extended from the southern tip of the Delmarva Peninsula up along the coast of New Jersey, with additional data collected along the outer coast of Long Island.

Monitoring was done entirely using AnaBat acoustic detector systems. The first acoustic monitoring sites were established onshore in February and March of 2009, and data-gathering will conclude in November 2010. Systems had to be protectively housed to withstand inclement weather, as data was recorded year-round.

Onshore detectors were mounted on three fire towers (at Lakewood and Dias Creek, NJ, and Snow Hill, MD), and one telescoping tower (in Lewes, DE).

Detectors also were mounted on three research vessels already conducting other offshore research. One vessel was researching marine mammals and birds off the New Jersey coast, operating 24 hours/day in 2009. Another boat operated by the Virginia Institute of Marine Sciences was trawling from Cape Hatteras, NC to Cape Cod, MA. A third boat was doing transects off the Maryland coast. Two AnaBat detectors were mounted on each of these boats, to provide a back-up in the harsh marine environment. Slide #14 shows some of the different boat tracks – green is the Virginia Institute of Marine Sciences, orange is the vessel looking at marine life within a proposed New Jersey wind energy site. Pink is the Versar, Inc. boat working off the Maryland coast.

### **Results**

Slide #15 graphs 2009 data from the four onshore detectors (two of which were working consistently). Peaks occur in the summer, low points in spring, winter, and fall. (We did get six calls at one of the detectors in January, which was surprising.) This year we recorded over 2000 calls in April alone, so it looks like the data from 2010 may be very different.

Slide #16 graphs preliminary offshore detections from 2009. Note that this data is broken out by date rather than by month, because we were not sampling continuously. Note that, although 18 nights of sampling data were recorded from early March to early June, only one bat was detected in the spring. By contrast, over the course of the fall (beginning in August), 117 bat calls were recorded. Most of the calls were identified as eastern red bats; quite a few were *Myotis* bats – including one detected up to 16 km offshore. I was surprised not to detect more hoary bats.

A total of 75 detections were made in the core study area (Maryland-Delaware-New Jersey). A total of 43 additional detections were made from three points within the northern part of my study area, from

the tip of Long Island to Massachusetts. Most of these detections (36) were made from a point 10.25 km off the northern tip of Long Island. Another three calls were detected near Block Island, and four calls were picked up at the northern-most detection point, 22 km from the coast of Massachusetts. The average distance from land for all offshore call detections was 10.24 km, skewed by the large number of calls picked up off Long Island. (The vessel from which these calls were detected was anchored in this spot for several days.)

### ***Implications***

The Maryland Department of Natural Resources is taking this data into account for planning of offshore wind energy development. It was not easy to get funding for this research, but I am hoping that the evidence of bats from this study will encourage funding of more comprehensive offshore pre-construction studies.

## Questions & Discussion

### ***How did you commandeer all these vessels?***

Sjollema: I e-mailed a lot of research institutions, and got a few replies.

### ***The Snow Hill station is very close to the inland rivers of the Chesapeake Bay. Why didn't you place the station further east, such as in Ocean City, Maryland? How could you be sure that these bats were offshore and not around the Pocomoke River?***

Sjollema: The purpose was to include onshore (near coast and above canopy) data for purposes of comparison.

### ***What was the onshore activity rate (# detections per detector per night)?***

Sjollema: Haven't calculated this yet.

### ***What was the height of the (onshore) towers?***

Sjollema: They are about 90 feet off the ground, except the one in Delaware which is about 30 feet.

### ***Was ultrasonic noise an issue for your boat detectors (i.e., did your data cards fill up, and was call quality affected)?***

Sjollema: My data cards did not often fill up but there was a lot of noise in all my files. Call quality didn't seem to be affected.

## Session 8. AWWI Research Priorities Panel

**Moderator:** [Taber Allison](#), *Massachusetts Audubon*

The American Wind Wildlife Institute's mission is to facilitate timely and responsible development while protecting wildlife and wildlife habitat. To help us determine where to invest our limited resources where they can have the most impact, we have asked our panelists to:

- summarize and synthesize what they heard at their respective sessions; and
- identify gaps in applied research that need to be addressed and provide "immediate" application.

The goal of this panel is to identify steps we can take to near term improvement in the way we site, build and operate projects. Just as we began this meeting by asking panelists to help us put the discussion of wind and wildlife research in the context of wind development, we now ask our concluding panel to take the results that have been presented and translate them into policy.

### **Panelists**

- Amanda Hale (Texas Christian University) – Fatality Impacts
- Dale Strickland (for Wally Erickson, WEST, Inc.) – Habitat / Behavior Impacts
- Doug Johnson (USGS Northern Prairie Wildlife Research Center) – Cumulative & Landscape Impacts
- Anthony Starfield (University of Minnesota *emeritus*) – Modeling
- Ed Arnett (Bat Conservation International) – Mitigation
- Jesper Kyed Larsen (Vattenfall Wind Power) – Offshore

### **Fatalities: Amanda Hale, Texas Christian University**

Over a third of this meeting's presentations and posters addressed fatality. Clearly, there are fatality estimation questions that remain to be resolved, and we need to keep in mind that we are not making these estimates in a vacuum. If we want to be able to figure out cumulative or population impacts, we need to have reliable estimates of fatality.

There is no one agreed-upon method for doing fatality research, but standardization of protocols increasingly allows us to compare data from year to year, and from site to site. The research community has moved towards using the number of fatalities per nameplate capacity as a metric. It is not clear whether we can move the next step to calculating the number of fatalities per MWh generated, which would give us a better common basis for comparison.

We need to develop methods to accurately predict fatality, and fund post-construction studies to assess those tools, especially for eagles, raptors, and other species of concern.

### ***Outstanding questions***

How do we go about conducting offshore fatality surveys?

How do we account for biases associated with fatality estimation methods? Manuela Huso and Regina Bispo have provided field biologists with some good tools.

What is the necessary search effort? Michelle Sonnenberg's poster does a good job of outlining what effort is required to get a biologically meaningful level of precision and accuracy.

A better mechanistic understanding of fatality also would be valuable. We need a reliable understanding of the source of mortality to determine which if any of our mitigation strategies are effective.

Researchers are in the field conducting daily fatality searches. Individual studies have generated a wealth of data that could be used by other people. I would encourage people with different skill sets to work together. Funds for research are limited; to keep up with the increasing pace of wind energy development, we should try to assimilate the data we have, and figure out what it is we have learned.

### **Habitat/Behavior: Dale Strickland (for Wally Erickson), WEST, Inc.**

Both the Wildlife Society and the National Academy of Sciences have emphasized the significance of indirect habitat impacts in the context of wind energy development. These impacts result primarily from the animal avoidance of otherwise suitable habitat as a result of the presence of a wind energy facility. Research questions highlighted in the presentations at this meeting included the following.

#### What is the distribution of behavioral response to wind facilities?

- How close does development need to be to have an effect (on nesting and nest success, for example), and what is the spatial and temporal distribution, and magnitude of those effects and what is the significance of these effects on population vital rates?
- If birds do use habitat near turbines, how does the proximity to wind energy facilities affect predation and parasitism, and how is this effect distributed in space and time and what is the significance of this effect on population survival rates?

#### Where species (such as Sage-grouse) are declining regionally – independent of wind energy development – how do we address the question of the role of impacts from wind energy facilities on these species?

#### Are habitat models useful in addressing risk?

- What do we need to know about biology and ecology of a species (such as the Indiana bat) to construct habitat models that predict the occurrence of habitat for a species?

#### What is the appropriate metric for species fitness?

- Is it reproductive success, daily survival rate, or something else?
- How do we distinguish wind energy effects on fitness from the effects of other factors?

#### Are Bald Eagles more likely than Golden Eagles to avoid turbines and thus avoid fatalities?

- Indications from a small number of turbines at one site support this hypothesis, but the hypothesis has not been tested.

Presenters proposed a variety of tools and metrics to use in assessing and addressing habitat and behavioral impacts, including the following.

- Joelle Gehring proposed the use of NEXRAD data to measure the importance of resources such as shoreline habitat to migratory species. Gehring noted that when we identify important habitat, we need to know how to determine appropriate buffer zones?
- Hall Sawyer's mule deer study proposes a Brownian bridge approach to looking at the distribution of effect of energy development on migration routes of migratory species.
- Todd Katzner demonstrated the use of satellite telemetry in assessing risk to Golden Eagles.
- Jesse Barber hypothesized that the noise generated by wind turbines may have indirect impacts that our present activity and fatality surveys do not capture.

An important point to take away from these presentations is that disturbances to the landscape that result in species avoiding habitat need to be taken into account.

### **Cumulative: Doug Johnson, USGS NPWRC**

The presentations proposed several approaches to looking at landscape- and population-level impacts, including the use of acoustic and radar tools to better understand bat movements, migratory behavior, and large-scale impacts of white-nose syndrome.

Yet none of these presentations truly addressed the question of how to measure cumulative impacts. Why? The short answer is: it's *hard* to measure cumulative impacts.

Even population impacts are much more difficult to measure than we would like to suppose. We can devise metrics to describe the adult population size, survival rate, and reproduction for a given population of animals. But how do we partition survival—or its complement, mortality—to distinguish what is additive and what is compensatory mortality?

Mallards, for example, are a very well-studied species, but although we know that about 10% of the mallard population is harvested each year, we cannot detect whether this harvest has any impact on population. It may be that reducing the number of mallards in the fall via hunting may allow remaining mallards to survive better over the winter because there is less competition for resources. We simply do not know.

Thus, if we are unable to detect a population effect for Golden Eagles at Altamont, it is not necessarily because there isn't one but because it is difficult to detect. That said, while it is hard to assess cumulative effects, it is even harder to prove that there is no effect.

The fundamental conflict between science and decision-making is that, as the pool of knowledge grows, the bigger the edge of that pool gets. In other words, the more we know, the more we know we don't know.

A question: Do we really *need* to understand cumulative effects? Perhaps on a proximate level, we don't. If a stressor kills 100 animals, for example, but compensatory action produces 100 more animals, might it be said that, from a policy perspective, the net effect is null?

### **Modeling: Anthony Starfield, University of Minnesota (emeritus)**

How do we identify modeling needs and modeling priorities in the context of wind energy research and policy? My recommendation is twofold:

1. Create a table, with “issues” (bat collisions, bird migration, cumulative effects, habitat issues, etc.) prioritized down the side and “types of models” (research models, design tools, preliminary decision tools, etc.) across the top. By filling in the cells – identifying which models might be applied to each issue, and whether these models are in the preliminary or testing stages, or ready to use, will help us to see where more work is needed and where the priorities lie.
2. Associated with this table, set up a database that has a paragraph or two about each model, clearly spelling out objectives, assumptions, data and how good or bad the data are.

Another recommendation, this time to improve the quality of modeling: Much of the modeling effort related to wind energy feeds into reports, predicting impacts, for Federal agencies such as the FWS. The quality of the models, and how they are interpreted, is likely to be highly variable. It would be wise to develop protocols for what you expect to see in a modeling report. For example, everyone modeling report should include a full assumption analysis and a thorough data sensitivity analysis.

### ***Building bridges***

In listening to the discussion at this meeting about applied research, I was struck by the image of the research community – academic and agency biologists – on one bank of a river and industry and stakeholders on the opposite bank. The purpose of applied research is to build a bridge from one bank to the other. Researchers are carefully constructing the bridge from their side and are busy talking about the bulkhead they are building on the south bank, but on the north bank you have industry asking “When will you reach our side?” and “Don’t you want to know what we’re doing over on this side?” It is crucial to start building some rope bridges from one bank to the other. One way to do this is for both communities to collaborate on quick, first prototype exploratory models that reach across the river.

For example, Ed Arnett “threw a rope” in his presentation by making a quick cost-benefit analysis of curtailment. This community needs to have more dialogue around this topic.

### ***Cumulative effects***

Granted, it is hard to measure cumulative effects. But, as Doug Johnson pointed out, that does not mean there aren’t any. Indeed, we have to be wary of what I would call the “Boogeyman” effect: no effect, no effect, no effect, and then bang – it all hits you in the face.

Given that, I would suggest building some exploratory models – break off pieces of this difficult problem and try to model these smaller pieces. How could we use habitat modeling to look at cumulative effects, for example? How could we look at sub-populations? Can we make the difficult problem of cumulative effects “go away” by (for example) focusing on resilience?

### ***What about policy issues?***

As a modeler, my recommendation for how to deal with messy policy problems – from the local to the global level – is to directly model the policy or decision-making process. This kind of modeling can have two valuable outcomes: First, thinking about policy and decision-making forces one to look at the science in a practical context and the policy in the light of the science. (This relates back to my comment about rope bridges.) Second, thinking about policy and decision rules preemptively and calmly can be of tremendous value. Think, for example, of the value of having guidelines in place, instead of reacting emotionally, when an endangered animal (e.g., an Indiana bat) gets killed. “Mediated modeling” is a structured way for stakeholders with possibly conflicting objectives to sit down and discuss decision-making before they find themselves in the midst of an emotional conflict.

## **Mitigation: Ed Arnett, Bat Conservation International**

The quality of the research efforts we are seeing has certainly improved, but some efforts still seem more like a “check-box” approach to monitoring, with post-hoc opportunistic analysis. The funding tail tends to wag the research dog, and we are better off pooling resources to move our understanding forward than throwing \$5 after a \$10 problem.

### ***Broad Themes***

#### **Curtailment and deterrence experimentation**

- As a strategy, curtailment needs to be fine-tuned (changes of cut-in speed and refining curtailment based on other factors like temperature, time of night, etc.)
- Curtailment based on real-time criteria (Wally Erickson’s presentation) needs a lot more testing, look at different parameter settings, & what about bats?
- Cara Meinke’s proposed range of curtailment regimes based on habitat suitability criteria also needs more testing.
- The jury is still out on whether an acoustic deterrent is going to be effective tool for bats.

#### **Off-site mitigation**

- We need to evaluate effectiveness of off-site mitigation, which has been promoted for a lot of species that were likely not to be killed in high numbers.
- White nose syndrome has changed this game, significantly complicating the issue.
- For migratory tree bats, I do not think off-site mitigation is helpful.

Are we mitigating or merely reducing, and can we wait to get the data. I think we need that data, but I don’t think we can afford to wait to start moving on curtailment strategies that have shown promise.

#### **Facility layout**

- Should facility itself be moved, or just a turbine? At this point, I don’t feel we have enough data to answer this question.
- It would be worthwhile to test the efficacy and requisite size of buffers. Buffer numbers get tossed around, and they should be viewed as testable hypotheses for all kinds of species and situations.

#### **Other considerations**

- How will changing technology influence our current thoughts? As turbine technology improves, cut-in speeds are going to drop, so we need to keep that in mind as we think about the cost of curtailment strategies.
- We also need to think about whether a proposed mitigation strategy scales up?

Decision-making frameworks are grossly lacking now. What data are required, and how will they be used? If I get 8 calls at one site and 80 calls at another, there’s no way for a researcher or agency to know what to do with that information. We need to think about this kind of question carefully and transparently if we want the research we’re doing to make a difference.

## **Offshore: Jesper Kyed Larsen, Vattenfall Wind Power**

In 2007 the national Environmental Group for offshore wind farms in Denmark identified the following four focus areas for a follow-up program to the 2001-2006 Environmental Monitoring Program, based on an analysis of key knowledge gaps and likely main issues for future development:

- Piling noise disturbance to harbor porpoises
- Habitat loss due to avoidance by wintering sea ducks and sea birds
- Cumulative impacts to divers (loons) and harbor porpoises
- Impacts of wind energy facilities on fish communities and fishery interests.

While this list of key issues was generated specifically within the Danish context, it suggests key research questions that might emerge here as well.

### ***Collecting offshore data***

The other offshore wind presentations at this meeting all related to the general question of how we collect wildlife data to inform offshore impact assessments and siting decisions. In particular, the studies presented explored and addressed the challenges, opportunities and limitations of using onshore data and applying standard onshore techniques in an offshore setting.

The general experience from Denmark and Europe is that it is possible to collect quality wildlife data offshore, but that it is considerably more difficult and costly; the level of ambition may need to be lowered for certain aspects. It may also require the development of new techniques, such as the use of high-definition (HD) aerial imaging stills and videos for efficient surveying of birds and mammals over large offshore areas. This now is standard in UK offshore projects.

### ***Building the knowledge base***

In the U.S. context, the situation would seem more to be one of starting to build up knowledge rather than “filling gaps.” In the short-term, a useful first step could be to establish protocols or guidelines to ensure sufficient quality and comparability of offshore wildlife data among projects, as has been done, for example, in the UK. Also, central efforts to improve the general baseline knowledge on species numbers and distribution on a regional and national scale will be valuable in terms of informing siting and impact assessments for individual facilities.

Eventually, it will be important to build up the U.S.’ record of experience with interactions between offshore wind energy facilities and key wildlife interests. For this I strongly recommend the large-scale demonstration approach adopted in Denmark, with a national research program that can efficiently build up knowledge early on. Critical to the success of such an approach is some level of central supervision and allocation of funds to ensure scientifically robust studies, and demonstration wind facilities being allowed in areas where the biological resources of main concern are sufficiently abundant to ensure that studies can draw firm conclusions.

Assessing individual or cumulative impacts of offshore wind facilities is a major challenge, as most offshore species are very poorly understood in terms of their population parameters, movement patterns, and even basic feeding ecology. The magnitude of this gap in knowledge may call for alternative thinking in dealing with potential wind energy facility impacts and associated decision-making questions.

## Concluding Discussion

Moderator Taber Allison referenced the FWS Wind Turbine Guidelines Advisory Committee's definition of "mitigation" as "avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts," and asked panelists:

***Of those three approaches [avoidance, minimization, off-site compensation], where do you think we'll have the most measurable impact? Of course we would rather avoid first, but where do we have greatest potential to make a difference?***

Responses - from panelists and other meeting participants – touched on the following themes.

Avoidance is difficult, in part because predicting impacts is difficult.

- Avoidance questions are difficult to answer.
- It is intuitively appealing to talk about predicting what will happen at a proposed wind power facility, but from a statistician's perspective, variation is always going to constrain our ability to predict impacts with any certainty.
- There is something to be said for the Ontario approach, where limited resources are put into pre-construction studies, and the focus is on post-construction monitoring and curtailment as necessary to minimize impacts.
- Nevertheless, siting in non-ecologically sensitive areas should remain the first priority. Minimization and compensatory mitigation becomes important as we start having to look at those more sensitive areas with unavoidable impacts.

The most effective approach depends on the species (or group) and types of impacts in question.

- For some species, there are opportunities to mitigate habitat loss; in other cases, minimization approaches are more effective.
- There are landscape-scale relationships that could be useful in doing pre-construction evaluation (at least for certain species and regions).
- In the case of bats, [one participant advocates] starting with avoidance, collaborating on the data that has already been collected, and concentrating on meta-analysis.

There is not any one approach; we need the full toolbox.

- In Portugal and other European countries, we are taking a pragmatic approach. It is very difficult to avoid mortality, and we recognize that we cannot solve everything at the same time. You have to use all three approaches. Each wind energy facility is different. Some sites are very close to each other with very different mortality rates.

The only way to get at landscape level and cumulative impact questions is to pool resources – across projects and disciplines.

- In Portugal, stakeholders met and defined some guidelines, and then instead of each developer doing monitoring and compensation measures, we agreed to do that on national level.
- It would be helpful just to be able to find turbine and wind energy facility site information all in one place.
- The FWS sees a need to take a much larger view of what's happening across the landscape [rather than looking just at project-specific impacts]. The agency is embarking on habitat

conservation plans (HCPs) that look at large portions of the western U.S., trying to get a handle on key species from a landscape level as well.

- In the UK, offshore environmental issues have been easier to address in the sense that (at a certain distance from shore) there is a common “landowner” – making it easier to gather data and tackle cumulative effects questions.
- A monitoring period of one year or less is not especially useful as a scientific tool. Several people have suggested pooling resources across facilities that are being built, so that more substantial research could be done.

The challenge is that most research is being done in response to a company that wants to know about a potential wind energy site, and the land area in question is relatively small compared with the range of a Golden Eagle, for example. If AWWI could get companies and agencies to work together – i.e., pooling the resources as well as the perspectives needed to do large-scale research – the hope is that everyone would benefit from being able to get answers to some of the bigger questions.

Other points raised in this discussion included the following.

- If we can look clearly and at a greater level of detail at how weather systems – not just temperature or humidity, but specific weather events – e.g. fronts, buffeting winds – impact mortality, we may be able to predict one or two hours or nights in the fall when you curtail operations.
- The impact of White nose syndrome is the single most important question, not just for wildlife, but broadly in terms of ecosystem impacts. [But this does not necessarily help the AWWI focus its research priorities.]

Facilitator Abby Arnold refined Taber Allison’s question by asking participants:

***How do we cut through fairly quickly to focus on what are the research priorities? Can we identify where developers want to develop, and what are the species we’re primarily concerned with in those areas, and then look at avoidance, minimization, compensatory options?***

Several respondents agreed that “we know intuitively what the issues and big problems are,” and that it would be worth trying such an exercise. However, the results (and value) of such an exercise would depend on who took part in it. Tony Starfield re-phrased this point, summing up the discussion with these remarks:

*The key words we are hearing are: “it’s hard” and “it depends.” We have heard people describe the researcher and agency maps, but we have not heard about the economic map. The first step is to aggregate everyone’s maps, and when you hear “it depends,” ask what it depends on, and when and where it depends. Until you put those maps and questions together, you’ll keep talking in circles.*

Moderator Taber Allison closed the discussion by acknowledging that, “as important as it is to get it right, it is also important to answer the questions and move forward.”

# Abbreviations & Index of Key Terms

## Abbreviations

Above-ground level (AGL)	Non-governmental organization (NGO)
American Wind Energy Association (AWEA)	Northern Prairie Wildlife Research Center (NPWRC)
American Wind Wildlife Institute (AWWI)	Office of Management and Budget (OMB)
Avian Bat Protection Plans (ABPP)	Pennsylvania Game Commission (PGC)
Avian Knowledge Network (AKN)	Programmatic environmental impact study (PEIS)
Avian Powerline Interaction Committee (APLIC)	Radar-absorbent material (RAM)
Best management practices (BMPs)	Resource selection functions (RSF)
Bureau of Land Management (BLM)	Rights-of-way (ROW)
Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly Minerals Management Service, or MMS)	Risk assessment matrix (RAM)
Conservation Reserve Program (CRP)	Rotor-swept zone (RSZ)
Constant false alarm rate (CFAR)	Shrub-nesting passerine (SNP)
Daily survival rate (DSR)	Supervisory control and data acquisition (SCADA) system
Discriminant function analysis (DFA)	United States Department of Agriculture (USDA)
Endangered Species Act (ESA)	United States Department of Energy (DOE)
Environmental impact study (EIS)	United States Department of Fish and Wildlife Service (FWS)
Environmental Monitoring Program (EMP)	FWS Division of Migratory Bird Management (DMBM)
Equivalent continuous noise level (Leq)	FWS Federal Advisory Committee (FAC)
Federal Aviation Administration (FAA)	White nose syndrome (WNS)
Global positioning system (GPS)	Wind resource area (WRA)
Global system for mobile communications (GSM)	
Habitat conservation plan (HCP)	
Important bird areas (IBAs)	
Incidental Take Permit (ITP)	
Lesser Prairie-Chicken (LEPC)	
Megawatt (MW)	
Memorandum of understanding (MOU)	
Migratory Bird Treaty Act (MBTA)	
National Environmental Protection Act (NEPA)	
National Park Service (NPS)	
National Wind Coordinating Collaborative (NWCC)	
Next Generation Radar (NEXRAD)	

## Key Terms Index

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## Appendix A: List of Poster Presentations

### ***Fatality Impacts to Birds and Bats***

*Direct Impacts to Birds and Bats at Four Wind Energy Facilities in Iowa, Minnesota, and South Dakota*  
Kristen Chodachek, WEST, Inc.

### [A Simple a priori Risk Estimator for Wind Projects Using Daytime Abundance Observations](#)

Caitlin Coberly, Merlin Environmental

*A New Method for Reliable and Repeatable Searcher Efficiency for Post-construction Mortality Surveys at Wind Energy Locations*

Benjamin Hale, Missouri State University

*Predicting Bird and Bat Fatality Risk at Prospective Wind Farm Sites Using Acoustic-Ultrasonic Recorders*  
Kevin Heist, University of Minnesota

### [Migratory Flight Patterns and Movement of Birds and Bats in Relation to Observed Mortality at Wind Energy Facilities in the Montezuma Hills, California](#)

Dave Johnston, H. T. Harvey & Associates

### [Mortality of Fledgling Hawks at Wind Projects](#)

Patrick Kolar, Boise State University

### [Who Ran Off With My Data? Estimating Carcass Persistence and Scavenging Bias in a Human-influenced Landscape in Western Alaska](#)

Ellen Lance, Anchorage Fish and Wildlife Field Office

*Improvement of Bird and Bat Carcasses Detection on Wind Farms Using Wildlife Research Dogs*  
Miguel Mascarenhas, Bio3, Lda.

*Bird and Bat Mortality Data in Portuguese Wind Farms – A Cumulative Analysis of 5 Years of Monitoring Surveys*

Sílvia Mesquita, Bio3, Lda.

*Combining Technologies to Assess Potential Impacts to Mexican Free-tailed Bats in Central Texas*  
Trevor Peterson, Stantec Consulting, Inc.

*Analysis of the Effects of Take on the Indiana Bat Population at a Proposed Wind Energy Facility*  
Shannon Romeling, Missouri State University

*Evaluation of Operations Personnel for Long-term Monitoring of Bird and Bat Fatalities*  
Jerry Roppe, Iberdrola Renewables

*Evaluation of Precision, Accuracy, and Cost of Fatality Estimation at Wind Facilities Following State and Federal Guidelines versus Other Monitoring Protocol*

Michelle Sonnenberg, WEST, Inc.

[\*Pre-construction Nocturnal Marine Radar Studies – What Have They Taught Us About Impact Assessments?\*](#)

David Tidhar, WEST Inc.

*Poisson Regression for Count Data: Application to Bird and Bat Mortality at the Wind Farm La Venta II, Oaxaca, Mexico*

Rafael Villegas-Patracá, Instituto de Ecología AC

### ***Impacts to Wildlife Habitat and Behavior***

[\*Mitigating Effects of Wind Energy on Loggerhead Shrikes: A Spatial Habitat Model\*](#)

Rob Bouta, Westwood Professional Services, Inc

[\*Management Implications of Individual Variability in Sensitivity to Noise within Wildlife Populations\*](#)

Jim Cummings, Acoustic Ecology Institute

[\*Do Operational Turbines Create a Barrier to Waterfowl Movement in the Prairie Pothole Region of North America?\*](#)

Jason Jones, Tetra Tech EC, Inc.

*Whooping and Sandhill Crane Behavior at an Operating Wind Farm*

Laura Nagy, Tetra Tech

*Assessing Golden Eagle Use of Wind Resource Areas Using Observational Data*

Kenton Taylor, WEST, Inc.

### ***Cumulative and Landscape-scale Impacts to Specific Species or Group***

[\*Predicting Wind Turbine Collision Mortality Using Spatial Models of Avian Abundance and Exposure\*](#)

Greg Forcey, Pandion Systems, Inc.

*Toward Landscape-scale Monitoring Guidelines for Wind Power Projects*

David Maddox, Sound Science

[\*Habitat Conservation Planning 201: The Winds of Change\*](#)

Kely Mertz, BHE Environmental

[\*Estimating Population-level Risks for Wildlife from a Landscape Perspective\*](#)

Rob Pastorok, Integral Consulting, Inc.

*Suitable Framework and Scale for Modeling and Managing Risk to Migratory Bats at Wind Projects*

Trevor Peterson, Stantec Consulting, Inc.

[\*Wildlife Information for Decisions, Planning, and Operations of Wind Energy Resources\*](#)

Jesse Schwartz, ICF International

***Mitigation Techniques and Technology***

[\*Using Radar-based Mitigation to Minimize Bird and Bat Strike Risk at Wind Energy Developments\*](#)

Jenny Davenport, DeTect, Inc.

[\*Lessons Learned From Habitat Conservation Plans: Applications for Wind and Endangered Species\*](#)

Alicia Oller, Tetra Tech EC, Inc.

***Understanding the Current Knowledge of Offshore Wind and Wildlife Issues***

*Addressing Environmental Effects of Offshore Wind Development*

Andrea Copping, Pacific Northwest National Laboratory

[\*A Simulation Model for Assessing Bird-Wind Turbine Collision Risk\*](#)

Christopher Nations, WEST Inc.

## Appendix B: Meeting Agenda

The meeting featured the following sessions and panels:

- Setting the Stage
- Fatality Impacts to Birds and Bats
- Impacts to Wildlife Habitat and Behavior
- Modeling
- Cumulative and Landscape-Scale Impacts to Specific Species or Groups
- Mitigation Techniques and Technology
- Understanding of the Current Knowledge of Offshore Wind and Wildlife Issues
- Research Priorities

To download the complete meeting program, which contains the agenda, please [click here](#).

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