Wind Wildlife Research Meeting X

Presented by American Wind Wildlife Institute

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Meeting Proceedings

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Prepared by:
Susan Savitt Schwartz, Editor

American Wind Wildlife Institute
1110 Vermont Avenue, NW, Suite 950
Washington, DC 20005-3544

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Abstract

Wind energy's ability to generate electricity without carbon emissions will help reduce the potentially catastrophic effects of unlimited climate change on wildlife. Wind energy also provides several other environmental benefits including substantially reduced water withdrawals and consumption, mercury emissions, and other sources of air and water pollution associated with burning fossil fuels. Adverse impacts of wind energy facilities to wildlife, particularly to individual birds and bats have been documented. Impacts to wildlife populations have not been documented, but the potential for biologically significant impacts continue to be a source of concern as populations of many species overlapping with proposed wind energy development are experiencing long-term declines because of habitat loss and fragmentation, disease, non-native invasive species, and increased mortality from numerous anthropogenic activities. These proceedings document current research pertaining to wind energy and wildlife impacts and innovations in technologies and methods to address these impacts, including: understanding risk, demographic impacts, fatality estimation, detection and deterrence technologies, and impact minimization and mitigation.

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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.

Disclaimer

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American Wind Energy Association (AWEA)
American Wind Wildlife Institute (AWWI)
Angled, linear and quadratic (ALQ)
Avian Power Line Interaction Committee (APLIC)
Bald and Golden Eagle Protection Act (BGEPA)
Bird Conservation Region (BCR)
Breeding Bird Survey (BBS)
Bureau of Land Management (BLM)
Bureau of Ocean Energy Management (BOEM)
Canadian Wind Energy Association (CanWEA)
Christmas Bird Count (CBC)
Daily fatality index (DFI)
Density weighted proportion (DWP)
Eagle Conservation Plan (ECP) and ECP Guidance (ECPG)
Electric Power Research Institute (EPRI)
Endangered Species Act (ESA)
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Global positioning system (GPS)
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Incidental take permit (ITP)
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Migratory Bird Treaty Act (MBTA)
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Next generation radar (NEXRAD)
Non-governmental organization (NGO)
Normalized differential vegetation index (NDVI)
Offshore Renewable Joint Industry Program (ORJIP)
Pacific Gas & Electric (PG&E)
Production tax credit (PTC)
Resource equivalency analysis (REA) [*In Ontario regulatory context:* Renewable Energy Approval]
Resource selection function (RSF)
Rotor-swept zone (RSZ) or area (RSA)
Supervisory control and data acquisition (SCADA) system
United States Department of Agriculture (USDA)
United States Department of Energy (USDOE or DOE)
United States Department of Fish and Wildlife Service (USFWS or the Service)
United States Department of the Interior (USDOI or DOI)
United States Geological Survey (USGS)
Video peak store (VPS)
White nose syndrome (WNS)
Wind energy area (WEA)
Wind resource area (WRA)

Welcome and Opening Remarks

Welcome

Taber D. Allison, Ph.D.
Meeting Chair and Director of Research and Evaluation, American Wind Wildlife Institute

Welcome to the over 300 attendees at this 10th biennial Wind Wildlife Research Meeting. This is an excellent open-forum opportunity to share research and to engage in dialogue. The American Wind Wildlife Institute (AWWI) wishes to thank our partners and friends, without whom a conference like this would not be possible.

AWWI received many more presentations than we could incorporate into the program, and I encourage all participants to spend time in the poster sessions, as there is a lot of important work being presented there. We will attempt to make as many of the posters and presentations as possible available online, with our proceedings to be published online in early 2015.

Opening remarks: retrospective and looking ahead

Abby Arnold
Executive Director, American Wind Wildlife Institute
Facilitator, National Wind Coordinating Collaborative Wildlife Workgroup

[presentation]

This is the tenth Wind-Wildlife Research Meeting since the National Wind Coordinating Collaborative (NWCC) convened its first research meeting here in Colorado in 1994. After 20 years of working together, we continue to look to this community to tell us: What are the questions we should be asking? What are the metrics and methods we should be using? What are the results of our analysis? What are the future issues to prioritize?

I want to thank everyone who has been part of this journey with me and with the AWWI staff: the partners and friends who participate in and support AWWI, U.S. Department of Energy, National Renewable Energy Laboratory, U.S. Fish and Wildlife Service, U.S. Geological Survey, the academic community, environmental organizations, consultants, and many more.

The factors driving the development of wind power have shifted over the years. In the 1970s, questions of economic and national security pushed us to turn to what was then called “alternative” energy. In the 1980s, Congress passed the production tax credit, which gave entrepreneurs the impetus they needed to invest in renewables. By the 1990s, states were setting targets for the contribution of renewables. Prior to 2012, climate change had not been addressed at this meeting. Taber Allison's presentation at our last meeting on climate, wildlife, and wind energy is now a published paper. In 2014, we had a call for action from the United Nations Secretary General for a response to climate change.

Concerns about the impacts of wind energy development on wildlife started in the 1990s – most markedly at the Altamont Pass Wind Resource Area in California. The National Wind Coordinating Collaborative (previously 'Committee') was formed in the 1990s and the first Avian Subcommittee organized to proactively address wildlife issues in wind development.

Today, the issues that face us are more critical than ever, but we have a community of excellence that is making real progress to provide solutions. Let us review a few of our accomplishments over the past two decades:

- In the early years, when wind power was starting to be recognized in the United States as a commercially viable source to produce electricity, NWCC experts identified the common questions and set of metrics and methods to study wind-wildlife interactions.
- By 2000, incorporation of wildlife considerations in siting and operations started becoming much more sophisticated as more projects were being built and results from studies were published.
- At that time, it became apparent that the Altamont was unique in some important respects, and not all wind facilities would have similar impacts. The scientific community also emphasized that consistent methods and metrics were needed in order to synthesize our understanding across sites. The first "metrics and methods" document was developed by expert NWCC volunteers in 1999; guidance for nocturnal species was published in 2007; "methods and metrics" was recently revised in 2011 and published as a *Comprehensive Guide to Studying Wind Energy/ Wildlife Interactions*.
- The years 2004 – 2010 saw the growth of the U.S. wind industry from 7 to 40 GW and a proliferation of collaborative efforts to focus on addressing the potential impacts of wind energy on bats, grassland birds, and sage grouse.
- In 2006, energy industry visionaries reached out to wildlife conservationists to work together, leading to the formation of AWWI in 2008.
- More recently, scientists began to recognize the importance of cumulative impacts and behavioral impacts and the need to place mortality estimates in context and consider landscape-level impacts. There was a focus on bats, and a call for a universal data repository. Experts recognized that the same levels of monitoring may not be needed at all sites, and that resources might be better invested in mitigation options.
- In 2012, the U.S. Fish and Wildlife Service released the voluntary Land-Based Wind Energy Guidelines, providing a framework to help wind energy project developers avoid and minimize impacts of land-based wind projects on wildlife and their habitats.

We have seen an extraordinary increase in activity, with over 60 GW of wind energy capacity now operational, and wind and wildlife policy is more dynamic than ever. New species are being listed, landscape-level habitat conservation plans are being developed. Climate change makes the need for wind energy more imperative, even as it increases the vulnerability of avian and other species, making the science of reducing uncertainty and developing solutions more important than ever.

If we can't do this together, then no one will.

In the past two decades, scientists and other experts have come and gone, helping us understand these issues. In particular I want to acknowledge two scientists who contributed a great deal. Dr. Thomas Kunz, whose work and leadership has made an enormous difference in our understanding of bat-wind interactions, had a serious accident a few years ago and is still in rehabilitation. Dr. Robert J. Robel, who passed away in 2013, shared his life-long commitment to studying grassland species, wind and other tall structure habitat impacts – along with his energy and enthusiasm for seeking solutions – with this community.

Latest Policies and Priorities

Wind Vision: a new era for wind power in the United States

Patrick Gilman, U.S. Department of Energy

The U.S. Department of Energy (U.S. DOE) is supporting research to transform the nation's energy system. Thirteen of the presentations or posters included in this Wind Wildlife Research Meeting are supported at least in part by U.S. DOE – from baseline studies of the offshore ecological situation to mitigation technology development and testing.

Wind Vision: A New Era for Wind Power in the United States is now in draft form, with an early 2015 publication date.[1] The two most important take-away messages from this document are:

1. Wind power matters to this country. It is a mainstream, viable part of our nation's energy portfolio, comparable to hydropower in terms of its contribution.
2. Wind power is valuable and there are a myriad of benefits it brings to this country that can improve our economic and environmental future, including the future of our wildlife.

In 2008, U.S. DOE issued a report projecting how our nation might achieve "20% wind by 2030." At the time, many questioned whether that was a plausible goal. But just five years later, we had not only met but surpassed the key targets – installed capacity (61 GW), costs, generation –

[1] The final report, *Wind Vision: A New Era for Wind Power in the United States*, was released in March 2015.

that the 2008 report projected for 2013. Wind energy has created 50,000 jobs with manufacturing facilities in 43 states. In terms of replacing fossil fuels, it has supplied us with energy equivalent to 270 M barrels of oil (which would have produced 115 M metric tons of CO_2 emissions), and reduced water consumption by 36.5 billion gallons.

The *Wind Vision* study is a scenario-based analysis grounded in the literature but also somewhat ambitious. The main scenario features a trajectory where wind power grows from 61 GW (supplying 4.5% of demand) in 2013 to supply 10% of the nation's energy demand by 2020, 20% by 2030, and 35% by 2050, based on achieving installed capacity totaling 405 GW. We compared this scenario against a baseline scenario, which caps wind power at its current contribution (4.5%), for all future years. These two scenarios constitute the primary analytical framework of this report, and all the costs, benefits, and other impacts presented in the report are calculated by comparing the differences between these two scenarios.

There are many documented inputs and assumptions, but at a high level the main inputs came from the Annual Energy Outlook 2014, renewables costs were derived from a literature review, and policy was modeled as currently legislated. This means that the production tax credit (PTC) was modeled and expired, and proposed rules were excluded from modeling. The Wind Vision scenario assumes that 85 GW of wind energy capacity is installed offshore, in addition to 320 GW of land-based wind energy capacity, estimated to require 1.5% of contiguous land use – about a third of what golf courses currently cover.

Keep in mind that *Wind Vision* is not a projection of the future, nor does it necessarily reflect a DOE goal or objective. Rather, this is a study that compares climate and economic impacts of two theoretical trajectories of long-term wind energy deployment, documenting an array of costs and benefits:

- Energy system costs go down as wind replaces fossil fuels
- $400 billion savings from avoided greenhouse gas emissions
- Air pollution reductions yield both cost savings and lives saved
- 23% less water consumed
- Other benefits include: energy diversity, less sensitive electricity prices, job creation, and local revenues.

Wind Vision includes a roadmap for achieving this aggressive yet credible scenario. The three major themes of this roadmap are:

1. Reducing the cost of wind energy so that it can compete without subsidy.
2. Expanding developable areas – not just maximize wind coexistence, but also expanding the transmission system.
3. Increasing economic value for the nation.

Figuring out the wind-wildlife questions is a key component of #2. Maximizing the potential for better coexistence of wind and wildlife requires more focused research into the risk factors for key species and a better understanding of key interaction factors, as well as better tools and techniques to monitor impacts and a focused effort to develop technologies to mitigate wildlife impacts. DOE already is pushing forward in these areas. We have or are preparing funding opportunities to develop mitigation technologies for bats, eagles and other species. We look to this community to get a better understanding of how to structure that support.

The wind industry perspective

John Anderson, American Wind Energy Association

This year the utility-scale wind industry passed its 40 year mark. It took the first 30 years to breech the 10,000 MW threshold, but then, largely as a result of the Production Tax Credit and other federal and state policies, only the next ten to reach 60 GW. During this same timeframe we have made significant advancements in technology – increasing capacity factors and domestic content while decreasing costs, and more importantly, improving our understanding of the industry's risks to wildlife and their habitats and developing techniques for avoiding, reducing, and mitigating for our impacts.

This year is also the 20th anniversary of the National Wind Coordinating Collaborative. NWCC grew out of concern over the observed impacts occurring at the early-stage utility-scale wind farms installed at the Altamont Wind Resource Area in northern California, and a desire by the industry, regulatory and conservation communities, and other stakeholders to understand why these impacts were occurring and seek ways to avoid and reduce them. This is the tenth time this community has met to evaluate the state of the science around wind energy's impacts and mitigation solutions – and each time we have come away with a better understanding of the issues and renewed sense of trust and collaboration. This kind of collaboration, between a self-reflective industry that cares enough to evaluate its impacts and such a diverse group of stakeholders as we see at these meetings, is truly an exception and not the rule.

No energy source – or really any human activity for that matter – is completely free of impacts, and wind energy is no exception. However, the wind industry's impacts must be considered in context; a cost-benefit analysis of its positive and negative attributes compared to those of other energy sources.

When comparing wind energy's impacts to other energy sources one must consider that generating electricity from wind provides significant benefits over its competitors in that it does not create air or water pollution of any kind (greenhouse gases in particular); it does not use water to generate power; nor does it require extraction, processing, or transportation of fuel; or generate hazardous waste that requires permanent storage. As a result, wind energy represents the lowest impact form of energy generation available to our society today. This fact is reinforced by a 2009 study conducted on behalf of the New York State Energy Research and Development Authority (NSERDA), which found that of all the energy sources evaluated (i.e.

coal, oil, natural gas, nuclear, hydro, and wind), wind energy has by far the lowest cradle-to-grave lifecycle impacts on wildlife and their habitats.

That aside, the wind energy industry takes pride in having been built on a legacy of care. We have worked alongside other stakeholders, expending significant resources in proactively seeking ways to minimize wind's relatively low impacts on wildlife, while offering an economical solution to mitigating the effects of climate change – which the broad scientific community views as the single greatest threat to birds and all wildlife.

Keeping this in mind, and knowing we have a limited amount of time to reduce our greenhouse gas emissions to avoid the worst effects of climate change, we must keep asking the relevant questions about wind energy's impacts and available methods for reducing them, but – recognizing that zero-impact is not realistic or achievable – we must also ask what is an acceptable amount of impact. A recent analysis has shown that collectively the wind industry has spent between $290 and 620 million dollars over the last decade alone to completing project-specific pre-construction surveys, post-construction monitoring and individual research projects designed to better understand the environmental impacts of wind energy and reduce them through informed decision-making processes. Nearly every major wind development CEO is aware these are critical issues and is committed to addressing them.

We know more than ever about wind's impacts and how to offset them, and continue to make advances to further reduce them – but given that the societal and environmental benefits of wind energy outweighs its impacts, we must recognize that this is an industry worth fighting for. At this critical point, we cannot allow a lack of perfect data on wildlife impacts to be a barrier to deployment. Thank you for your work to date, as without this collaboration and all of your hard work we not have a foundation to build on. So think critically, think outside the box, and think about which questions we can move beyond and what outstanding questions really need to be addressed as we responsibly develop more wind energy over the next 20 years, 40 years, and beyond so that we leave this world a better place for future generations.

United States Fish and Wildlife Service

Christy Johnson-Hughes, U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (the Service) is often seen in the role of enforcer: "If you don't change your ways, bad things will happen!" But our agency does not want to be viewed this way. We are all working towards the same goal of developing the wind energy resource while protecting wildlife. The Service is developing policy elements intended to provide useful tools for all stakeholders, and we need everyone's help to make this happen.

Our focus is on eagles and migratory birds; we recognize the need to address bats, prairie chickens, and other wildlife, but the focus here is on migratory birds. The Bureau of Land

Management (BLM) has been an important partner in this (see Brian Novosak's presentation, below).

The Migratory Bird Treaty Act (MBTA) is a tough act for wind. It is a strict liability law – a single take is illegal. But birds strike things – including wind turbines. The Service is developing a series of tools for our field offices to better understand and analyze migratory bird impacts from wind as well as other resources so that we can get expedite permitting processes, providing useful analytic tools and habit mitigation strategies.

We acknowledge that there is a difference between Golden and Bald Eagles, and that we cannot treat every species the same when they have different behaviors. We want to hand industry a clear list of what they need to do to avoid disturbing nests, and we are looking at behavioral elements within eagle populations, so that we can give our partners (state agencies, tribes, NGOs, industry) information that they can use to create avoidance and mitigation strategies for eagles. We are working with BLM to figure out how eagles are impacted on federal lands – again, so that we don't put unnecessary delays on the industry.

With regard to eagle take, we recognize that there is a lot of frustration with the permitting situation. The Service held a series of scoping meetings earlier in 2014, and we are still assembling the many constructive comments we received. The agency is looking very seriously at this input, in an effort to make the take rule more "user friendly." We are looking at a broader range of mitigation options, including such innovative practices as the use of conservation banks, in-lieu fees as well as lead-abatement and other measures.

The MBTA does not allow an incidental take permit for migratory birds, but we are looking at a range of options. We do not want to burden our own staff or the industry with a cumbersome permit process, but we are working with our partners to figure out what a migratory take permit would look like and how it would function.

The Service has set up an injury and mortality reporting system. It is designed to track incidental take of eagles and migratory birds at various facilities eventually, but right now wind. Its purpose is not enforcement, but rather, to study what is happening and use the information to develop options for avoiding, minimizing, and compensating for impacts.

The Service has the planning tools, and we want to improve those and give them to partners up front, early during the project design and development process, rather than after substantial commitments have already been made. We are taking steps together to improve our knowledge so that we can conserve many of these declining species while growing our wind energy industry. Industry is helping us by providing research funds and helping us understand what is happening out on the landscape.

Bureau of Land Management wind initiatives

Brian Novosak, Bureau of Land Management

[presentation]

There are several wind initiatives underway within the Bureau of Land Management (BLM):

1. Competitive Leasing Process – Proposed Rule sets up a framework to promote use of preferred areas for wind and solar energy development on public lands. See: http://blmsolar.anl.gov/documents/docs/FR_Competitive_Leasing_Sep_30_2014.pdf

2. West-wide Wind Mapping - This is an 11-state mapping effort that includes existing exclusion zones and sensitive areas at 200-m resolution scale. The data will be used to create a GIS-based interactive website with downloadable data files. The site is anticipated to go "live" in March 2015.

3. Wyoming Wind and Transmission Study – BLM Wyoming is taking the lead in adding local data (e.g., sage grouse core areas) to national wind and transmission reports. The Wyoming study provides a scenario-based report of areas with high restrictions, designed to inform applicants early about sites to avoid.

4. Other initiatives:
   a. National Greater Sage-grouse Planning Strategy – a 12-zone, 6-state effort
   b. Eagle use and productivity monitoring – surveys since 2010 across all BLM western states to inform responsible siting. BLM is working with state agencies and the conservation community to gather information about what is happening on the ground.
   c. Eagle take permit guidance
   d. Bat studies, kit fox surveys (Utah), Ferruginous Hawk use and productivity monitoring

We have piloted landscape-scale planning with solar and are now exploring it with wind. Our goal is to find ways to be **more** efficient at identifying wildlife and other resource impacts, and to work with industry to resolve those impacts.

Environmental organization perspective

Julie Falkner, Defenders of Wildlife

Defenders of Wildlife is looking both offshore and onshore, at transmission issues as well as energy generation. Our work takes place more at the national level, on policy issues rather than specific projects. We are thinking about how wildlife and wind energy can co-exist, and how we can embed within the broader policy context the concept outlined in the U.S. Fish and Wildlife Service's wind guidelines, of guiding development to low-conflict areas.

If we are to achieve the scenario outlined in the U.S. Department of Energy's Wind Vision report, we will have to get above only looking at project-by project level decision-making and also start looking at the landscape scale, at population level impacts and at landscape mitigation opportunities. Department of the Interior (DOI) Secretarial Order 3330 directs the previously established DOI Energy and Climate Change Task Force to develop a coordinated strategy on mitigation practices to "effectively offset impacts of large development projects of all types through the use of landscape-level planning, mitigation banking, in-lieu fee arrangements, or other possible measures." Defenders of Wildlife is using this as a launching point for getting beyond project-by-project reviews, and to get stakeholders and agencies to think about programmatic efforts.

Federal agencies are under-resourced right now, in terms of both financial and human resources, so we have to come together to support each other. This is especially true after the recent election. This is going to be a challenging Congress, and we must prepare to be dealing with endangered species and other environmental policy issues in a very "dynamic" political environment.

We have spent a lot of time thinking about avoidance, and now are thinking more about compensatory mitigation. But we can neither avoid nor buy our way out of everything, so we must look more closely at the minimization of impacts – at what opportunities exist and how to make the most of those, so that we can make development more efficient without losing our wildlife heritage.

Defenders of Wildlife gets a lot of calls about individual projects, but it is here at meetings like this one where we have an opportunity to have productive conversations that can advance decision-making on the larger scale.

Bats and Wind Energy: Turbine Interactions, Population Impacts and Fatality Minimization

Monitoring bat activity and behavior at wind turbines using thermal imagery and ultrasonic acoustic detectors

Presenter: Cris D. Hein, Bat Conservation International

[presentation]

Co-Authors: Paul Cryan (USGS, Fort Collins Science Center); Marcos Gorresen (University of Hawaii at Hilo); Manuela Huso (USGS, Forest and Rangeland Ecosystem Science Center); Michael Schirmacher (Bat Conservation International); Robb Diehl USGS, Northern Rocky Mountains Science Center); Kevin Heist (University of Minnesota); Frank Bonaccorso (USGS, Pacific Island Ecosystems Research Center); Doug Johnson (USGS, Northern Prairie Wildlife Research Center); David Hayman (Colorado State University/University of Florida); Paul Fricker (The MathWorks, Inc.); David Dalton (Wildlife Engineering)

PROBLEM / RESEARCH NEED

Although wind-generated electricity is renewable and generally considered environmentally friendly, greater than anticipated bat fatalities have occurred at wind-energy facilities worldwide. Over last decade, we have accumulated a lot of information about bat activity and impacts. Yet despite considerable efforts to quantify the impact of wind energy development on bats, there is a paucity of information regarding *why* bats interact and collide with turbine blades.

A number of hypotheses suggest bats may be attracted to turbines as potential feeding, roosting, and mating sites, yet investigations focusing on bat behaviors near turbines are lacking. There have been relatively few studies to help our understanding of bat behavior around turbines. Cameras are expensive, special types of equipment are needed, and it has been difficult to get high enough resolution images. In recent years, however, costs have come down and resolution has improved, making these studies more feasible.

Objectives

The objective of this project was to use infrared videography to:

1. Examine bat activity and behavior near the rotor-swept zone (RSZ).
2. Assess whether blade rotation influences activity.
3. Understand the environmental conditions under which bat/turbine interactions are most likely to occur.

APPROACH

Between July 15 and October 3, 2012, we monitored bat activity, behavior and fatalities at the Fowler Ridge Wind Energy Facility in northwest Indiana. Three treatments were applied to the turbines: non-operational; normal operations; and feathered up to a cut-in speed of 6.5 m/s. Daily fatality searches conducted within 80-m radius plots, with searchers walking parallel transect lines spaced 4 m apart. Bat activity around the study turbines was monitored using radar, acoustic detectors and near-infrared and thermal videography cameras:

- Acoustic detectors were positioned on the nacelle (facing away from the blades). Acoustic data were compiled over 10-minute intervals, identifying high frequency and low frequency bat calls, as well as hoary bat calls (a subset of low frequency).
- An all-weather vehicle-mounted 25-kW x-band radar unit with high grain, parabolic antenna was positioned at a distance of about 2 km to monitor the rotor-swept zones of three different turbines.
- Information from near-infrared (NIR) and thermal surveillance cameras was compiled over 10-minute intervals:
    - Hitachi KP-E500 & AVT Prosilica GX1920 NIR cameras were positioned 30 m away from the turbine base. These could be focused on the entire RSZ or zoom in to focus on the turbine nacelle and upper tower. LED and laser illuminators were used.
    - Axis Q1921-E thermal surveillance cameras were positioned 12 m from the base of the turbine, and zoomed to image about two-thirds of the RSZ.

We used Kolmogorov-Smirnov and chi-square tests and logistic regression to assess patterns of bat detection in relation to behavior, wind speed, and turbine operation.

FINDINGS

A total of 1,304 hours of thermal imagery yielded 993 bat observations, including behaviors such as hovering, flight loops and dives, repeated close approaches, and chases. About 79% of our video observations were identified as bats. We did not see a trend in activity with time of night. Bats were detected more frequently at lower wind speeds and most bats altered course toward turbines during observation. Video observations show bats exhibiting “focal behavior” – moving toward the turbine – in some cases spending minutes near the turbine before moving out of the field of view.

Focal behaviors were categorized as “single approach” (72%) or “multiple approaches” (27%). The most common “close encounters” (bats within 2 m of the turbine) were nacelle investigations (n = 258), followed by tower investigations (n = 110) and blade investigations (n = 55). Most close encounters occurred when blades were moving slowly (<1 rpm) or not at all. Bats possess hair-cell receptors on the surface of their wings that allow them to sense minute changes in airflow. Bats tend to be active on the leeward side of natural features, where conditions are favorable for finding prey as well as commuting. When turbine blades were not rotating, bats were much more likely to approach from the leeward side, much as they would a tree or other natural feature. The proportion of leeward approaches increased with wind speed when the blades were feathered, but when turbines were operational, leeward side approaches decreased, suggesting that turbulence created by the spinning blades may disrupt the animal's ability to make sense of the airflow pattern.

We observed higher activity during moonlit periods. Echolocation calls were detected during only 22% (n = 218) of the video observations; the bats we observed either were not echolocating; or they were doing so above the range of the camera. (This is likely due to lack of overlap in the detection areas of acoustic detectors and video cameras.) The acoustic calls we did record did not indicate that bats were pursuing nor capturing insect prey on or near the turbines.

We did not see most of the targets picked up by radar, which were presumably birds. It seems that birds are not interacting with turbines in the same way bats are, even if they are in the wind turbine area. We also noted – as other researchers have done – that it is hard to find bat collision fatalities on the ground.

CONCLUSIONS / APPLICATIONS

This kind of research is not necessary at every project site, but the data can advance our understanding of why certain bats are vulnerable to wind turbines, and also may assist in refining operational minimization strategies and placement/orientation options for acoustic deterrents to reduce bat fatalities at turbines.

- If bats are mostly coming from leeward direction, it may be better to focus deterrent applications there.
- Rather than continuing to raise cut-in speeds, it might be effective to extend the decision to resume normal operations, or slow the ramp-up speed, creating an uncomfortable airspace for bats before the blades are spinning at a risky rpm.

"Behavior of Bats at Wind Turbines" was published by the Proceedings of the National Academy of Sciences, PNAS October 21, 2014 vol. 111 no. 42 15126-15131. Video footage can be viewed online at http://www.pnas.org/content/early/2014/09/24/1406672111.full.pdf+html.

Questions & Discussion

Q: What percentage of observed bat investigations resulted in a strike, or conversely, what percentage of bat investigations resulted in avoidance behavior? Any indication that avoidance behavior is learned?

A: Two percent of observations resulted in strike or near-strike. We did not classify anything as avoidance, although there were bats that passed straight through the field of view. A very small percentage did not seem at all interested in turbines.

Q: How did you identify targets as birds, bats, etc?

A: By the shape, size, and flight pattern. Originally we ran and viewed videos manually, but we have developed a software system to use for final analysis.

Q: How fast is too fast for a turbine to start up?

A: We don't know what the lethal rpm is for bats. If bats are perceiving wind cues and had enough time to recognize and get out of the way, they might be able to leave the RSZ in time. We would need to test, try a couple different ramp-up profiles to see what was effective.

Q: Would you position deterrent devices downwind of the turbine?

A: It is worth investigating. If we could limit the number of deterrents needed, it would help reduce cost and logistics of mounting these devices. However, we still want to maximize the conservation value of acoustic deterrents. A study is needed to look at the effect of different placements/orientations of deterrents.

Q: How was Fowler Ridge study funded? Were you able to look at species-specific differences?

A: BP, with supplemental funding from BCI and USGS.

Q: Any idea why Tory found feeding buzzes at turbines, while Cris did not?

Tory: Different surveys; we focused on towers, while Cris focused on nacelle area.

Cris: Yes, different sampling design.

Exploring potential hypotheses behind bat-wind turbine collisions

Presenter: Victoria Bennett, Texas Christian University

Co-Authors: Amanda M. Hale, Alison J. Schildt, Brent G. Cooper, Aaron M. McAlexander, Dean A. Williams (Texas Christian University)

PROBLEM / RESEARCH NEED

Considerable progress has been made toward understanding patterns of bat fatalities, estimating bat fatality rates, and identifying the proximate causes of bat mortality at wind facilities; and yet, we still do not know why bats come into contact with wind turbines. Two basic hypotheses have been proposed:

- Fatalities are random or coincidental events and simply reflect bat activity, abundance, and behavior.
- Bats are attracted to wind turbines. Attraction factors are species-specific, and may result from wind turbines providing actual resources, perceived resources – or simply being objects of interest.

These two explanations are not mutually exclusive and multiple factors are likely contributing to bat mortality at wind turbines. If we are to develop practical solutions to minimize the negative effects of wind turbines on bat populations, we must discover the ultimate causes of bat-wind turbine interactions.

Objectives

The objective of this project was to investigate some of the factors that could be contributing to bat-wind turbine collisions and to determine whether wind turbines provide or appear to offer one or more resource: water, food, shelter, mating opportunity, connectivity.

APPROACH

Over a five-year period (2009-2013), we monitored bat fatality at a 112.5 MW wind facility in the southern Great Plains. For each of the six species (including two migratory species) that are being killed at this facility, we developed species-specific resource maps to identify possible "hotspots" where bats were likely to be abundant and active. Resources mapped included water, roost sites, foraging areas, and commuting routes.

We then explored whether fatalities were correlated with resource availability to see whether bat fatalities reflected resource-driven levels of activity and abundance.

We then evaluated several attraction hypotheses, using night vision and acoustic surveys to observe bat activity in the vicinity of the turbines, and other types of surveys (including collection of feces) to assess bat activity across the wind farm. We looked specifically at whether turbine lighting was correlated with fatalities, and at whether bats were using turbines as roosting resources. We also did DNA sampling of invertebrates at turbines, in combination with DNA barcoding of bat feces to detect whether bats were foraging in the vicinity of the turbines.

FINDINGS

If bat fatalities are a function of bat activity and abundance, we would predict turbines near resource hotspots to have high levels of fatality compared to those with little or no resources. However, for eastern red bats, the majority of fatalities were happening where there were no resources at all. For other species, our analysis revealed that while fatalities did occur at turbines near resource hotspots, fatality levels were low. In contrast, about 40% of the fatalities occurred at a small subset of turbines in areas with no known resources, leading us to conclude that resource availability does not adequately explain bat mortality at wind turbines.

Our data confirmed that bats are not attracted to FAA lighting on nacelles; bat fatality was significantly lower at turbines equipped with FAA lights than at those without.

Other types of surveys did indicate that the wind turbines themselves may be attracting bats. For example, we found bat feces in the door slats and around the base of towers, suggesting that bats were foraging and potentially roosting at turbines. Night vision and acoustic monitoring surveys confirmed that bats were actively foraging in the immediate vicinity of turbines and that bats were coming into contact with turbine towers with the same approach and posture as bats drinking at local water sources. Finally, invertebrate sampling at turbines, in combination with DNA barcoding of bat feces, indicated that the invertebrate prey in the bat feces comprised some of the most abundant invertebrate species found on or around turbines.

CONCLUSIONS / APPLICATIONS

Collectively, these data suggest that wind turbines could be an important foraging resource for bats and that bats may perceive wind turbine tower surfaces to be water. In summary, our surveys suggest that bats are behaving around wind turbines as though they were resources and mortality may be effectively reduced if turbines can be made less attractive to bats.

Questions & Discussion

Q: ***Did you account for spatial variation in fatalities among turbines when looking at the effect of turbine lighting? Are there plans to install lights at other turbines?***

A: No. We are looking at how bats visualize things, could see if light makes a difference. Lights only affected eastern reds, not any of the other species. I think most of the time lights don't make a difference.

Q: ***Given your findings, any suggestions about optimal turbine design? Will you be looking at how to deter that behavior (e.g., by changing the surface of the tower)?***

A: We are using flight room to test different textured vs. smooth surfaces, and water, vertical vs. horizontal surfaces.

Q: ***Have you made a connection between the "skimming" behavior at turbines and mortality rates?***

A: Because the night vision camera we used to observe skimming does not allow us to identify species, we cannot correlate with fatalities – unless we can match up video with acoustic data that gives us species identification. We're still analyzing some of that data. The video matches up with eastern red calls. Hoary bats fly a lot higher (up by the nacelles), where they are not picked up by acoustic detectors. We have not yet matched skimming to the bat calls to identify species.

Q: ***What were the resources you mapped to create the resource hotspot maps, and were they defined differently for hoary vs. red bats?***

A: I GPS-mapped all the water, and mapped all the trees (over 10,000 trees in the area) and other potential roosting sites, identifying distinguishing features of importance for specific species of bats. I also mapped foraging areas and commuting routes.

Q: ***Could lack of resources mean bats are more actively searching for resources, leading them to investigate the turbines? Was historical land use/vegetative cover investigated in areas where resources are not currently available?***

A: Yes, absolutely; especially if they are migrating through.

Q: ***Is there a difference in the sound profiles of blades rotating at different speeds?***

A: Yes, but I don't know the extent of how those differences would affect bats.
Kaj Skov Nielsen: More than rotation speed affects acoustic profile – e.g., vortex generators, pitch of blades.

Questions submitted but not addressed during session:

Q: ***How many instances of "skimming" behavior did you observe?***
A: Fourteen of 468 observations were observations of potential drinking.

Q: ***Any plans to look at the top of nacelle (a more horizontally-oriented surface) for drinking/skimming behavior since its orientation is more like the surface of water?***

A: No plans, but the nacelle is a smooth horizontal surface so we would hypothesize drinking attempts would happen there.

Q: ***Do curved metal surfaces have the same echo/acoustic profile as water and flat metal surfaces****?*

A: The arc of a turbine is so large and the echocolation wave is so small (4 inches spread perhaps) that to an echolocating bat the surface essentially is flat.

Q: ***How far from tree habitat did you see foraging activity taking place?***

A: Within 40 m.

Q: ***How was this work funded?***

A: NextEra Energy Resources.

Modeling encounters between migrating bats and wind projects

Presenter: Christopher S. Nations, Western EcoSystems Technology, Inc.

[presentation]

Co-Author: David P. Young (WEST, Inc.)

PROBLEM / RESEARCH NEED

With increased threat to the endangered Indiana bat (*Myotis sodalis*) from white nose syndrome, there is growing concern over incremental impacts of anthropogenic origin including wind energy development.

Objectives

Develop a simulation model to aid evaluation of the potential encounter rates of Indiana bats at individual wind projects during seasonal migrations.

- Provide a tool for allocating predicted take to hibernacula and maternity colonies
- Evaluate relative risks of wind projects at different locations

APPROACH

The model relies on state and federal sources of data on hibernacula locations and the adult female population sizes of each hibernaculum, along with published migration records and maternity colony habitat characteristics (percentage of forest cover, altitude/latitude gradient), while recognizing that colony locations are generally unknown. Typically, the recovery unit (in this case, the Indiana bat RU) defines the total bat population and the region of interest. All bats in the RU are *potentially* affected; bats outside the RU are *not* affected. In addition to colony sizes and locations, other unknowns include the migration routes between the hibernacula and the maternity colonies.

Our approach to this large, multivariate optimization problem is to split it into two smaller problems, with hard data and assumptions fed first into the numeric component, and numeric outputs from this component along with additional data and assumptions feeding into the spatial component (slides #10 & 11).

1. Numeric Component: In the first stage of the simulation, maternity colony sizes (mean, minimum, and maximum) and the number of bats "contributed" by each hibernaculum to each maternity colony are randomly generated. We assume that each hibernaculum contributes to each colony, and vice versa.

2. Spatial Component: Colonies are randomly placed within suitable habitat, with constraints such that locations satisfy a minimum (~ 5-mile) inter-colony distance criterion and mimic distance and direction distributions of migration data. There are several steps and decisions to determine if a colony location is valid.

   Hibernacula are connected to colonies by straight migration paths, with width of 5-20 km to account for uncertainty in actual migration pathways. An "encounter" is defined as any overlap of a migration path with the wind project. By design, encounters represent potential interactions of migrants and a project, but not any aspect of direct impact such as collision risk.

FINDINGS

Results from simulations for several individual wind projects in different RUs indicate that encounters are generally infrequent though distributed among a large number of hibernacula and maternity colonies. Also, the number of bats migrating within encountering paths typically represents a small proportion of the RU population.

We repeated the simulation hundreds of times to generate a map showing the path density and the bat density within paths (slide #16). We have also considered the assumption that recovery unit boundaries are closed; in some cases, an open boundary between recovery units may be reasonable.

CONCLUSIONS / APPLICATIONS

Potential refinements to this model include:

- Looking at other species of bats
- Using RSF modeling to refine maternity colony habitat
- Modeling more realistic migratory movements (e.g., following riparian areas)

Quantifying incidental take requires additional assumptions and/or modeling, though encounter rate represents an important component of take estimation. Alternatively, if take has already been estimated by other methods, results from this model can be used to estimate the allocation of take among hibernacula and/or maternity colonies. Software is being developed as a desktop tool for use by the U.S. Fish and Wildlife Service. In addition, our approach may be useful to wind energy development companies seeking to minimize risk to migrating bats through siting considerations.

Questions & Discussion

Q: *Has any validation of maternity colony location/density been done with known maternity sites?*

A: No, not yet. We are in the process of collecting data from state agencies to examine this.

Q: *What is plan for validating model? Did your model predict known Indiana bat fatalities (e.g., Fowler Ridge)?*

A: This is a model validation question. No, we have not looked too closely at how predicted encounters match known fatalities. We have looked at a couple of projects in the Midwest, and so far it doesn't look like there is high correspondence between predicted encounters and fatalities. There is a lot more that goes into predicting fatalities that is not really addressed by our encounter model.

Q: ***What was your maximum migration distance?***

A: Based on telemetry and band recovery data, maximum migration distance of Indiana bats in the Midwest is 375 miles (604 km). Available data from the East indicates that migration distance is typically much shorter.

Geographic origin and population size and structure of bats experiencing mortality at wind energy facilities in the central Appalachians

Presenter: David M. Nelson, University of Maryland Center for Environmental Science

Co-Authors: Cortney Pylant, Matthew C. Fitzpatrick, J. Edward Gates, Stephen R. Keller (*University of Maryland Center for Environmental Science*)

PROBLEM / RESEARCH NEED

Bats are vitally important in controlling insect-related crop damage and preventing the spread of insect-borne plant and human pathogens. Understanding the impact of wind-turbine mortality on bat populations is therefore a high priority for global conservation and environmental health. However, such understanding requires data regarding bats' regional habitat use and population size and structure, which are currently lacking for many impacted species.

The majority of wind turbine-related fatalities are tree-roosting bats. Two highly-impacted species are *Lasiurus cinereus* (hoary bat) and *L. borealis* (eastern red bat). These long-lived, long-distance migrants are cryptic and reclusive. They are solitary for most of the year, and not much else is known about them. Traditional monitoring methods are not effective; we need alternative methods to monitor populations.

Objectives

To get at the question of whether fatalities are sustainable, we used hydrogen isotope analyses and looked at population genetics to determine:

- Is turbine mortality impacting only local bat populations or those across a broad geographic extent?
- What is the effective population size and temporal stability of bat populations experiencing mortality, and do these populations exhibit subpopulation structure?

APPROACH

The central Appalachians is a region of ongoing wind-energy development with one of the highest bat mortality rates in the world. We took fur and tissue samples from 246 hoary bats and 144 eastern red bats, representing carcasses collected in 2003 and from 2009 through 2012.

Hydrogen isotope Ph exhibits a gradient from more negative in precipitation occurring at higher latitudes to more positive at lower latitudes. The relationship between between the δ^2H of precipitation and hair samples from bat carcasses is often species-specific, and is known for both hoary and red bats. We were able to use classification accuracy of known-origin museum bats to model the probability of origin (local or non-local) of turbine-killed bats relative to the location of mortality.

For each species, we then compared microsatellite DNA with mitochondrial DNA to gain insight into population structure, effective population size and temporal stability. Microsatellites are repeating sequences of 2-5 base pairs of DNA that result from slippage during DNA replication. They are highly polymorphic and evolve relatively quickly, and can be used to identify differences at individual level. Mitochondrial DNA evolve more slowly, and reflect uni-parental (maternal) inheritance.

FINDINGS

We found different origins and evolutionary histories for these two commonly killed bat species:

- Eastern red bats killed at Appalachian turbines are local, part of a single, diverse, unstructured, large population (effective population size in the several millions) that has recently expanded following bottleneck event.
- Hoary bats killed at these turbines likely represent a less diverse subpopulation comprised of both local and non-local bats with an effective population of thousands to tens of thousands of individuals.

If our sample of hoary bats is just one of multiple regional subpopulations distributed in different areas of North America, then sustained mortality in each subpopulation would decrease effective population size at a faster rate than the same level of mortality occurring in an unstructured population. Consequently, a level of mortality that might not severely impact an unstructured population where all individuals are potential partners may be detrimental to the long-term stability of a genetically structured population.

Female hoary bats migrate to higher latitudes during the summer. We also noted a high variation in the percentage of non-local hoary bats at Pennsylvania wind farms, suggesting that these sites may not be located in migratory corridors.

CONCLUSIONS / APPLICATIONS

Our data suggest that eastern red bats may be better able to absorb sustained mortality than hoary bats, and that hoary bats have less evolutionary potential to respond to environmental changes than do red bats. Continued mortality of hoary bats may therefore have long-lasting impacts on population size and stability. Lack of genetic structure for both species suggests that impacts may be spread throughout each of the two populations.

Overall, our results illustrate that stable isotopes and population genetics are powerful tools for monitoring bat populations being impacted by wind-energy development. Future research questions are:

- What are continental-scale migration pathways?
- Do hoary bats display subpopulation structure across North America?
- Have there been any recent changes in effective population size?
- Are turbine-killed bats representative of larger population?

Questions & Discussion

Q: ***Have you done any analysis of Myotis bats in terms of population size and origin?***

A: No – that is on our to-do list if someone has the money! It would be great to compare census known counts with genetic-based estimates of population size. Conversion factors are well-known for salmon, for example, but not for *Myotis* or bats in general.

Q: ***If you split your sample of museum bats into two parts and estimated isotopes, how consistent would the estimate be?***

A: Are you asking how we convert the hair sample and precipitation isotopes? The uncertainty is incorporated into our likelihood-of-origin mapping. (See the poster for the regressions.)

Q: ***Can you explain what is meant by local vs. non-local? Are you suggesting that local bats are non-migratory?***

No. Most of the bats were killed during the fall migration period, but we are suggesting that they originated within a couple 100 kilometers of where they were killed. They could have summered in that region and could still be long-distance migrants on their way down to Cancun for the winter.

Questions submitted but not addressed during session:

Q: ***Do all bats molt hair in the same manner? In other words, does hair sampled from different parts of the bat influence the hydrogen isotope values?***

A: I'm not aware of a study that has investigated if hair from different parts of a bat have different hydrogen isotope values.

Q: ***Hoary bat effective population size approximates the number of these bats being killed each year. What does this tell us about persistence probability?***

A: It's important to remember that effective population size (what we measure from the genetic data) is not equivalent to census population size (or numbers of individuals being killed each year), so we can't directly infer probability of persistence from our result. However, our data do indicate that red bats have a much larger effective population size than hoary bats, which suggests that red bats may be better able to absorb sustained mortality than hoary bats.

Investigating the benefits of fine-tuning curtailment strategies at operational wind facilities

Presenter: Amanda Hale, Texas Christian University

Co-Author: Victoria Bennett (Texas Christian University)

PROBLEM / RESEARCH NEED

Large numbers of bats are being killed at commercial wind facilities worldwide, and thus developers and natural resource managers are under increasing pressure to reduce or mitigate the impacts of wind energy on these species. Raising cut-in speeds (i.e., the speed at which turbines begin to produce energy into the power grid) from 3-4 m/s to 5-6.5 m/s has proven to effectively reduce bat fatalities at wind facilities in Alberta Canada, the upper Midwest and other U.S. locations. Because this type of curtailment incurs a loss in power production, there is a need to fine-tune the conditions under which wind turbines are curtailed to achieve the maximum benefit to bats while minimizing financial costs.

Objectives

The primary focus of our study was to determine if we could improve the effectiveness of curtailment by incorporating other predictors of bat mortality.

APPROACH

We have been monitoring fatality annually at a 112.5 MW wind facility in north-central Texas since 2009. Wolf Ridge Wind Farm in northwest Texas is characterized by cattle pastures, hayfields, and some winter wheat, with a forested slope leading to the Red River.

During the peak fatality season (July through September) 2009 and 2010 we conducted daily fatality searches at 14-16 of the 75 wind turbines at this site, salvaging over 600 bat carcasses and looking at fine-scale mortality patterns. We obtained weather data for the same period in 10-min increments from an on-site meteorological tower. We observed high inter-annual variation in fatality rates. Daily fatality rates were also highly variable, both within a season and among species.

We used general linear models with an information-theoretic approach to determine which weather variables best fit the observed pattern of bat fatality, measured as a daily fatality index (DFI), across both years. We used wind speed, wind direction, temperature, and barometric pressure in our modeling, as these variables can be readily gathered at operational wind turbines and used to inform curtailment strategies in real-time.

Using these results, we devised a curtailment strategy with variable cut-in speeds, ranging from 3.0-6.5 m/s depending on wind direction. Three treatments were randomly assigned to 30 turbines (10 groups of 3):

- 3.0 m/s cut-in speed
- 5.0 m/s cut-in speed
- cut-in speed varied from 3.0 to 6.5 m/s depending on wind direction

Curtailment was implemented through the supervisory control and data acquisition (SCADA) system from 30 minutes prior to sunset until 30 minutes after sunrise from July through September 2011-12. Fatality searches were conducted at two-day intervals.

FINDINGS

Our modeling exercise indicated that a combination of wind speed and wind direction best predicted bat mortality at our site: DFI was highest at low (<5.0 m/s) and moderate wind speeds (>5.0 m/s and <6.5 m/s) when the winds were out of the northeast and southeast. Wind speed alone explained only 20% of the variation in daily fatality index, but mean overnight wind speed in combination with wind direction was the best predictor of bat mortality at our site, especially for hoary bats (*L. cinereus*). Bat mortality was highest when winds were out of the northeast and southeast, across a range of wind speeds.

In 2011, we found no difference in bat mortality among treatments. This year was a record drought year in Texas and estimated bat mortality was less than a tenth of estimated mortality in 2009 and 2010. We speculate that migratory bats move with storm fronts and not one of these systems passed through our study site during the survey period in 2011.

In contrast, 2012 had a more typical rainfall pattern and both curtailment groups had significantly lower bat mortality than the control. In 2012, we observed a 61% to 88% reduction in bat mortality due to curtailment with no difference between the two curtailment strategies, but we were unable to analyze cost due to a server failure.

NextEra agreed to two more years, extending the experiment to all 75 turbines (25 groups of 3) for 2013-14. Full plot searches were conducted at 12 turbines; gravel pad and road searches were conducted at 63 turbines. Curtailment resulted in a 69 to 91% reduction in bat mortality over the control group, with no difference between the two curtailment strategies. Power generation was reduced by 0.34% in 2013 and 0.73% in 2014. Although the costs varied between years, it appears that the wind speed only strategy had a much lower cost than the speed and direction curtailment.

CONCLUSIONS / APPLICATIONS

Despite a similar reduction in mortality, the financial costs of the two strategies could differ. A more detailed financial analysis is underway, but it appears that the most cost-effective strategy for reducing bat mortality in the southern Great Plains is curtailment at 5 m/s, and that there is no advantage to incorporating wind direction. We recommend broadly implementing curtailment at 5 m/s across North America, July through September.

Questions & Discussion

Q: *Might speed & direction curtailment be more cost-effective if you used 5 m/s in the East/NE/SE and actually dropped cut-in speed from other wind directions?*

A: Yes, reducing cut-in speed from 6.5 to 5 m/s would reduce power loss; however, we were trying to determine if we could increase the reduction in bat mortality by further raising the cut-in speed. During July-September, the wind almost never is coming out of the west and southwest at this site. We could do more with this analysis, but given the amount of resources it took to get this data, I would say it is not warranted at every site. In terms of policy, we have a clear recommendation for 5 m/s to 5.5 m/s cut-in speed.

Q: *Did you see a difference in mortality numbers from surveying the entire plot area vs. road-and-pad surveys? Could this difference have skewed your findings?*

A: For the first four years, we looked at the proportion of road-pad vs. rest of plot. About 40% of carcasses are found on roads. Today's analyses only looked at carcasses from road/pad. We would have to go back to compare plots.

Q: *Your study ended at the end of September; do you have any information about migratory movement later in the fall – e.g., into October or even November?*

A: We do monitor fatality into October. The numbers drop off precipitously after the end of September. I don't know about fatality in November, but we do have acoustic data year-round indicating that bats are active beyond the period in which we monitor fatality.

Q: *What parameters, conditions, or agreements were in place for the developers to allow research to be conducted, and what can be done to get other developers to allow "publishable" research to be conducted at their facilities?*

Cris: We only will work with companies that allow us to use and publish; the condition of such agreements is that we do not share the raw data.

Amanda: The TCU-Oxford University-NextEra Energy Resources wind research initiative began what was meant to be a 5-year partnership looking at wind-wildlife interactions, economic impacts, etc. A key condition of the partnership is that the researchers would be free to publically share their findings and publish in the peer-reviewed literature. We share data. NextEra has been generous about sharing weather and power data with TCU and Oxford, but with the understanding that we use but do not publish the raw data without their permission.

<u>Questions submitted but not addressed during session:</u>

Q: ***If almost no LACI were found dead after winds were out of East, why did you curtail at 6.5 when wind was out of East?***

A: We were trying to provide coverage for eastern red bats which comprised the greatest number of fatalities in 2009 and 2010.

Q: ***How many bats in a night translates to a high-fatality night?***

A: In terms of absolute numbers, I don't know. We looked at the range of nightly fatality we found from July through September and called nights that were greater than ~1 standard deviation above the mean "high fatality" nights.

Q: ***Why does curtailment including both speed and wind direction have a higher cost? (This result seems counter-intuitive.) Could it be tweaked to have the same cost?***

A: It had a higher cost because under some wind directions, the cut-in speed was raised to 5.5 or even 6.5 m/s (higher and therefore more costly than 5.0 m/s). The combination of wind speeds and directions that we tested could be further modified to try to bring down the cost while maximizing the benefits to bats; however, I think our data suggest this may not be necessary.

Q: ***Is the non-significant difference in hoary bats attributable to lower sample size / low power?***

A: I think this question refers to the results from 2012 and the answer is that I don't think so. We found a significant difference in mortality for eastern red bats with a total sample size of 23 bats. During that same time period we found 31 hoary bats and no difference among treatments.

Q: ***Do you have any ideas why wind direction was so important? Could it have been related to location of suitable habitat relative to the turbines?***

A: We don't know.

Q: ***Re treatment where cut-in speed varied with wind direction, at what rate could the SCADA system be updated and communicate with the wind turbines (e.g., once nightly, every hour, every few minutes)?***

A: The SCADA system was in constant communication with the wind turbines, although we set some rules to prevent turbines from repeatedly switching from curtailed to non-curtailed states when wind speed and direction were low and variable. For example, the wind needed to be coming from one direction for 5 minutes before the decision to curtail was implemented.

Q: ***How was the power loss due to curtailment calculated? What does the percentage decrease in power generation equate to in dollars?***

A: At this point in time, I'm not able to report the power loss in dollars.

Q: ***Was the percentage lost from total production (24 hours/365 days), or was it from the study period (1/2 hour prior to sunset to end of curtailment period)?***

A: It was over the entire 12 months in 2013 and the first 10 months of 2014 (the data from November and December were not available for analysis at the time of the meeting).

Eagles and Wind Energy: Monitoring, Point Counts, and Populations

Efficient and effective eagle monitoring protocols

Presenter: Paul Rabie, Western EcoSystems Technologies, Inc.

[presentation]

Author: Wallace Erickson (WEST, Inc.) **Co-Authors:** Paul Rabie, Kenton Taylor, Kimberly Bay, Kristen Adachi, Todd Mattson (WEST, Inc.)

PROBLEM / RESEARCH NEED

Eagle take concerns and the ability to apply for eagle take permits for wind projects has led to the need for efficient and effective carcass monitoring protocols for eagles. The U.S. Fish and Wildlife Service (the Service) needs reasonable assurances the take limits for projects are not being exceeded, while industry wants to be sure costs of monitoring are not excessive and ultimately oversample.

According to the Service's Wind Energy Guidelines:

- The intensity of the studies should be related to risks of significant adverse impacts identified in pre-construction assessments
- Monitoring should be conducted for at least one year, unless information from nearby studies can help quantify impacts
- Monitoring depends on the question: What are the fatality rates of species of concern (e.g., eagles)?

Most monitoring studies have been designed to estimate fatality rates for multiple groups, including small birds (e.g., songbirds), bats as well as larger birds (e.g., raptors). However, an effective monitoring plan for small birds or bats likely oversamples in terms of search frequency and other factors in the goal is estimating eagle mortality.

Objectives

The objective of this study was to provide a statistical evaluation of the factors that affect the accuracy and precision of eagle fatality estimates, including search frequency, number of turbines to be searched, searching techniques (transects vs. scans), carcass removal rates, surrogate birds in trials and plot size.

APPROACH

We reviewed public data sets from 27 projects, summarizing monitoring protocols and empirical data on:

- Carcass removal and searcher efficiency of large raptors compared to surrogate species (e.g., pheasants)
- Search techniques comparing walking transects to driving and scan searches
- Distance sampling techniques compared to the more common approaches currently in place.

Project facilities averaged 92 turbines, with an average of 63% of those being searched. The average length of study was 21 months. We compared the results of studies using different search techniques, evaluating the marginal cost relative to improved accuracy and precision. We also compared studies where monitoring was done by a traditional consultant vs. operations staff monitoring as part of their operational work.

FINDINGS

Study Duration

Length of study averaged 21 months. Monitoring duration should be driven by study objectives: for example, is the objective to get a precise snapshot of how many eagles were taken over one year, or to look at trends over multiple years?

Carcass Persistence and Search Frequency

Large raptors persist; 80% of carcasses typically remain for searchers to find for 50 days. Small raptors persist for perhaps 20 days. While we do not have specific eagle persistence data, anecdotally, we hear that they are very persistent. Small raptors typically last as long as surrogates (mallards and other tasty fowl.)

Search Protocol

The traditional search protocol involves walking transects. It is highly effective for a range of taxa, but it is time-consuming: from 30 minutes to two hours per turbine. The transect protocol is needed for small birds and bats, but given that 7 of the 14 eagle fatalities found in the 27 studies we reviewed were incidental finds, the transect protocol may not be needed for eagles. An alternative method is to drive, circle, and scan. We know that eagle fatalities do not land close to the turbine, but (based on using turkeys as surrogates in searcher efficiency trials) the visibility of carcasses in open habitats is as much as 100 m.

Meta-analysis of searcher efficiency trials suggests high searcher efficiency rates for large raptors (94%) compared to surrogates (74%) and smaller raptors (58%).

CONCLUSIONS / APPLICATIONS

From this review, searcher efficiency rates were significantly higher and carcass removal rates were significantly longer for large raptors compared to the surrogate species used in most bias trials, suggesting use of surrogates will likely lead to an overestimate of eagle fatality.

Preliminary evaluation of the data suggests that for many sites, the most efficient and effective monitoring approach is one that varies effort depending on the topography and vegetation at a plot, doesn't include narrow transects in moderate to high visibility, and accounts and incorporates all sources of possible detection (incidental finds by operations personnel and others and searches) in the estimation.

Preliminary results also showed that, for eagles specifically, operational staff are able to monitor more turbines at a significantly lower cost and with higher searcher efficiency than the traditional method of hiring consultants. (Note, however, that industry still needs to rely on consultants for bias studies.)

Questions & Discussion

Q: ***You mentioned a 30-120 minute search time for transect searches. What is average search time for drive, circle, scan method?***

A: That depends on how much carcass processing you have to do. One can search a turbine in under 15 minutes, but if a searcher spots something 110 m out and has to go out and process that carcass, obviously it will take longer. But mostly 15 minutes or less per turbine.

Q: ***Please address bias of having operations staff conducting searches as opposed to a neutral third party.***

A: You can begin to address that by having a consultant place the bias trial carcasses when conducting searcher efficiency trials. Iberdrola has found that if staff are well-trained, they become quite invested in the process, and they are excited to work with the program and generate good data.

Q: ***What color were turkeys used as raptor surrogates for searcher efficiency experiments?***

A: We used turkey decoys with a harness of real (black) feathers.

Q: ***How do you account for eagle skeletal remains that would have a lower probability of detection than intact carcasses?***

A: It's a good question – one we struggle with. As eagles age, their detectability changes; the distance-detection curve for a fresh eagle is different than for an old eagle. At the moment we're taking the conservative approach that if there is less than a complete carcass we consider it undetectable. Essentially what we're saying is that eagles become undetectable quickly, because we haven't been able to estimate the detectability by age and distance response surface – I would be interested to hear if anyone has ideas about that.

Q: ***Did your eagle monitoring protocol look at injured eagles? If not, could the protocol be modified to look at eagle injury as well as eagle mortality?***

A: We did not find any eagle carcasses or injured eagles. Injured eagles would be treated as fatalities for estimation purposes. This is standard practice in most post-construction monitoring studies.

Golden Eagle point counts and telemetry data: a project-specific comparison

Presenter: Laura Nagy, *DNV GL Energy*

Co-Authors: Melissa Braham, Adam Duerr and Tricia Miller (West Virginia University); Chris Farmer and Emily Mix (Tetra Tech, Inc); Amy Fesnock and Larry LaPre (Bureau of Land Management); Todd Katzner (West Virginia University, U.S. Geological Survey, U.S. Forest Service)

PROBLEM / RESEARCH NEED

Many wind project developers and owners are trying to evaluate collision risk to eagles. Telemetry and point count data provide useful but different information on how eagles use a project area. GPS telemetry data provide highly detailed, accurate data about the spatial and temporal patterns of individual birds. In contrast, point-count data provide a subset of spatial and temporal eagle use data, but these data represent all eagles using a project area.

Objectives

How do we identify high use areas? Point counts and GPS telemetry generally are used independently. We looked at a project where both methods were used, to try to determine to what extent they yield similar conclusions.

APPROACH

We looked at telemetry and point count data collected simultaneously for a project in Southern California. Two Golden Eagle nests were active during the period (2012) when both types of data were being collected: one inside the project boundary, one within 3.2 kilometers of the project.

- Telemetry data were collected for three eagles: one adult male telemetered in January, and one adult male and one fledgling telemetered in May.
- Point count data were collected weekly between March 2011 and June 2012 from eight mountain-top point count locations and three valley point count locations.

Individual flight paths were first drawn on a map and then digitized. The digitized point count data were used to generate flight path frequency distributions using ArcGIS with a 250 m by 250 m grid. Each grid cell was assigned a value based on the number of flight paths, with flight paths closer to the grid cell centroid point being more heavily weighted when calculating the cell’s mean frequency value.

During the same period, West Virginia University (with funding from BLM) was gathering GPS data from 3 eagles in the same area. GPS data (latitude, longitude, altitude) were transmitted over GSM (cellular) phone network at 15-minute intervals. Using telemetry data within 500 m of the project footprint, we created utilization distributions based on bivariate normal kernel density estimates, and used these to generate monthly home range isopleth maps representing the most concentrated 50%, 75%, and 95% of eagle locations. We then compared these with a map of flight path densities derived from the point counts.

FINDINGS

Both telemetry and point count data identified the area in the vicinity of the eagle nest closest to the project area as the highest use area. The data differed in that the telemetry data covered an area much larger than that of the point counts; however, point count data showed eagle use at the southern end of the project that was not used by telemetered eagles.

CONCLUSIONS / APPLICATIONS

Preliminary interpretation suggests that although telemetry data provided detailed information on eagle use within and outside of the project area, point count data increased the understanding of eagle use throughout the project area by capturing the movements of eagles without telemetry. When information is needed on general patterns of use by larger numbers of individuals, point counts likely are more useful. Similarly, telemetry data are more suited to assessing behavioral patterns of individuals. Both methods can be used to model behavior over larger spatial and temporal scales. Therefore, both methods are relevant to evaluate collision risk to eagles, but implementation will depend on the project-specific objectives.

Questions & Discussion

Q: *Which do you think will provide more insight into eagle use during migration or winter – telemetry or counts?*

A: The challenge of dealing with migration is that you telemeter the eagle and it then leaves the area. So it depends on the question you're trying to answer. If you're interested in where the telemetered birds are moving through the area, then that would be a useful method. Point counts are more informative about eagles moving through an area and general use patterns. Both pieces of info can be useful because we don't know that much about eagle behavior during the winter or migration; point counts can help improve understanding of eagle behavior within a project area, but telemetry helps us understand the bigger picture, which is how are eagles using the wintering areas and where are they coming from or going to. As a rule, when we mark birds, we find out that our assumptions about behavior are often no longer valid.

Q: *Why were two male birds picked for telemetry, and how does movement of males differ from that of females?*

A: Males were picked because they happened to come to the traps. Regarding male versus female movement – females spend long periods of time incubating and brooding, so not as much time moving around. During other parts of the year, movement behavior is not that different; we see extensive movements by both male and female eagles.

Q: ***From a permitting perspective, is the point count data adequate for an ECP? Or do we need the detailed information that requires telemetry monitoring?***

A: The Eagle Conservation Plan guidance addresses take in terms of putting "eagle use minutes" into a Bayesian fatality model. The typical way of handling eagle fatality estimates in an ECP is to use the point count data. Telemetry can add information about risk or inform use, but that's not incorporated directly into the Bayesian fatality model as it is currently designed.

Q: ***How much do eagle use areas overlap based on whether telemetry or point count methods are used to determine use? Is resource selection similar between these two survey methods? Can you quantify?***

A: We did not make a quantitative comparison for this presentation, but we are discussing how to do that.

Q: ***Was interaction between telemetered and non-telemetered eagles monitored? Do territorial birds deter presence of floaters?***

A: Although we did document interactions, we did not have telemetry data in real-time, so there was no way to tell if it was between telemetered vs. non-telemetered birds.

Population status of eagles and availability of eagle take permits while maintaining the goal of stable or increasing eagle populations

Presenter: Kenton Taylor, Western Ecosystem Technology, Inc.

[presentation]

Co-Authors: Ryan Nielson, Todd Mattson, Elizabeth Baumgartner (WEST, Inc.)

PROBLEM / RESEARCH NEED

The 2009 Bald and Golden Eagle Preservation Act (BGEPA) permit rule authorizes take "compatible with the preservation of the eagle" for otherwise lawful activities. The 2009 Federal Environmental Assessment (FEA) proposed annual eagle take thresholds consistent with the goal of stable or increasing breeding populations. Given uncertainty, the U.S. Fish and Wildlife Service (the Service) set take limits at no more than one half the Maximum Sustainable Yield or up to 5% of annual production (whichever is lower).

Take thresholds are managed nationally, at the eagle management units (bird conservation regions for Golden Eagles and Bald Eagle management units for Bald Eagles), and at the local-area population scale. In the case of Bald Eagles, the limit is 5% (1% in cases where demographic data are lacking or questionable) of annual production or half the maximum sustainable yield, whichever is lower, to ensure that stable or increasing breeding populations are maintained. Because the best available data for Golden Eagles in 2009 indicated modest declines in the four bird conservation regions (BCRs) that constitute 80% of the Golden Eagles' range in the lower 48 states, the Service will consider issuance of permits only for safety emergencies and programmatic and other permits that will result in a net reduction in take or a net national take of zero Golden Eagles. (At the local area scale, a permit may be issued for take up to 5% of the estimated local area population with compensatory mitigation.)

The Service contracted Western Ecosystems Technologies, Inc., to develop and conduct a western-wide survey for Golden Eagles. The minimum five-year review period for the 2009 permit rule has now concluded, and new information from the survey may warrant a modification of take thresholds.

Objectives

The current rule codifies a conservative approach that almost certainly underestimates the harvest potential of the Golden Eagle population. The objective of the western-wide survey is to gather better demographic information and systematic population monitoring to help inform management decisions.

According to the 2009 FEA, if Golden Eagle data and modeling warrant an increase in thresholds, the Service would begin to authorize take at no greater than 1% of annual productivity, unless information available at that time demonstrates that higher levels of take can be supported.

APPROACH

The Western Wide survey began with a pilot study in 2003, and was restarted in 2006. Its objective is to monitor Golden Eagle populations in the four BCRs (Great Basin, the Northern Rockies, the Southern Rockies/Colorado Plateau, Badlands and Prairies) that constitute 80% of Golden Eagle's range in the lower 48 United States. We analyzed annual results from the Western-Wide surveys 2006 through 2013 to:

- Estimate yearly status and trends in Golden Eagle abundance
- The Survey data give us 80% power to detect an average of a 3% decline per year over a 20-year period using a 90% confidence interval

Survey Method

The Western Wide survey involves three observers in a Cessna flying at 107-150 m above ground level (AGL), recording all Golden Eagles seen on transects. The same transects are covered from first light to 12:30 pm, late August to early September every year. Observers record whether eagles are flying or perched, and note group size, GPS location, age class, and AGL. Having a third observer in the back of the plane allows us to simulate a mark-recapture and to estimate the probability of detection.

FINDINGS

As reported in Milsap et al. (2013), there is a general correspondence between the Western Wide Surveys and the Breeding Bird Survey (BBS) Data, suggesting that BBS data (going back to 1968) were providing useful trend information not only for the four BCRs with Western Wide Survey Data, but also for eight other BCRs through 2010. In general, we see slightly declining trends in the southern BCRs and slightly increasing trends in northern BCRs. The average rate of population change across all 12 BCRs from 1968 to 2010 was +0.40% per year (95% CI = -0.27% to 1.00%), suggesting a stable population, and clarifying that Golden Eagles are not declining widely in the western United States (Milsap et al. 2013).

CONCLUSIONS / APPLICATIONS

These latest information on eagle populations suggest that the no-net loss standard might be unwarranted for Golden Eagle populations while still maintaining stable or increasing populations. Using take level calculations consistent with the 2013 Eagle Conservation Plan Guidance and the final Environmental Assessment for the eagle permit rule, we conclude that allowing take of 1-5% of annual production in the west might still provide for stable breeding populations. However, any change in thresholds would be determined by the Service.

In April 2012, the Service issued an Advanced Notice of Proposed Rule Making. The Service initiated public input on eagle management objectives in July and August 2014. Management objectives must be in accordance with BGEPA, and ultimately will determine the amount of permitted eagle take that can be allowed. Updating the current quantitative approach is one possibility; another alternative would be a more qualitative approach such as “to not meaningfully impair the Bald or Golden Eagle’s continued existence.” Any changes to management objectives are not likely to be implemented before 2016 at the earliest.

Questions & Discussion

Q: ***Isn’t the maximum sustainable yield defined independently of population size? Your slide indicated some relation.***

A: It also depends on the demographic parameters for the population you’re looking at: their survival and production.

Q: ***Can we expect to see a central or east-wide mapping tool analogous to the west-wide mapping?***

A: I can’t speak for the Service. Surveys so far focus on the four Bird Conservation Regions that constitute 80% of eagle populations in the U.S.

Bob Murphy (Service): It’s being considered. Kenton mentioned we’ve added a winter survey component recently. The Milsap paper gives us a way to estimate trends in other areas; I don’t know that an eastern mapping tool should be expected. The Service can make suggestions as to the type of compensatory mitigation measure to be used for Golden Eagles, but we leave it to the developer to propose ideas that they can make work. We are working with others to develop alternatives (carcass removal, lead abatement, ultimately habitat conservation) – the key criterion is that we can quantify its effectiveness.

Q: ***How is "1-5% of annual production" measured for determining available take?***

A: In 2009, it was based on estimated annual average production from demographic parameters that the Service had at the time.

Q: ***How do two observers on right side simulate mock capture-recapture?***

A partition prevents front and back-seat observers from seeing what the other is doing.

Q: ***Have the surveyors compared fixed-wing surveys with the much slower and more thorough helicopter surveys? Don't most state agencies use helicopters?***

A: For nest surveys, yes, but not for population status or trend monitoring like what we were doing. We have not made any comparisons.

Q: ***Will the western-wide eagle surveys be made publically available? If so, when – and will you provide GIS data or just maps?***

A: Reports from the surveys are currently available. WEST has published a couple of papers in the Journal of Wildlife Management (Nelson et al. 2013). We have to defer to the Service about use of the GIS data, as they own that data.

Eagles and Wind Energy: Understanding Risk

Assessing landscape-scale risk factors for eagle mortality on power lines

Presenter: Lucas Bare, *ICF International*

Co-Author: Paola Bernazzani (ICF International)

PROBLEM / RESEARCH NEED

Recent changes in Bald and Golden Eagle Act permitting have prompted wind facilities to develop eagle conservation plans (ECPs), which are required to obtain programmatic take permits. These plans are also applicable to utilities, including existing infrastructure with the potential to take eagles through collision and electrocution. (It is estimated that 1-25% of eagle fatalities continue to result from electrocution, despite efforts to design and retrofit poles and lines with bird safety features.)

Pacific Gas & Electric (PG&E) is preparing the first utility wide ECP, covering a 49-million acre plan area with an extensive network of power lines: 18,600 miles of transmission and 141,200 miles of distribution lines. Because the U.S. Fish and Wildlife Service (Service) ECP guidance focuses on fatalities from turbines, there is a need to translate recommendations for assessment of take to electrical transmission and distribution infrastructure.

Objectives

We analyzed fatalities associated with PG&E's above-ground power lines to determine whether landscape-scale factors could be used to predict risk of power line-related fatalities.

APPROACH

Wind energy facilities can cover extensive areas, but in most cases the infrastructural footprint is fairly well defined. By contrast, assessing risk across a utility's entire service area requires a broad landscape-level assessment approach that can help target areas for more in-depth analysis of appropriate avoidance, minimization, and monitoring activities.

We hypothesized that power line density and habitat quality could influence eagle mortality risk across a landscape. We mapped power line density (at a 10-square km scale) across the plan area. We then assigned "eagle use" ratings (at a 1-square km scale) based on landscape features:

- Bald Eagles – based on proximity to major water features (lakes, rivers, reservoirs)

- Golden Eagles – based on landcover type (assigned a value of high, medium or low – with hardwood woodland and herbaceous cover as high, and barren, urban, water, and agriculture as low use)

Combining the power line density and highest use areas gave us risk rating ranges from 2 (low density/low use) to 7 (highest density/highest use), at the 1 km grid scale.

To test the hypothesis, we used eagle fatality data compiled service area-wide by PG&E from 2002 through 2012. First, we assessed the risk of fatalities according to habitat quality. Next, we assessed the mortality risk to eagles from the interaction of power line density and habitat quality, assuming that areas with the highest power line density and highest habitat quality could present the highest risk of eagle mortality.

FINDINGS

Proximity to water was highly predictive of risk for Bald Eagles: 96 percent and 93 percent of fatalities occurred within 10 kilometers and 5 kilometers of a major water feature, respectively. Landcover type was predictive of risk for Golden Eagles. More fatalities than expected, based on their proportion of the study area, were documented in herbaceous (49% of fatalities vs. <20% of the land area), agriculture (26%), and urban land covers (12%), but only the trend for herbaceous land cover was statistically significant (Prob>Chi-Square <0.0001).

Habitat quality was more influential of risk for both Bald and Golden Eagles, with the highest proportion of fatalities occurring in the highest quality habitat. The proportion of eagle fatalities declined within the highest power line density classes, as eagles may not frequent these areas due to their lack of habitat (e.g., urban areas).

CONCLUSIONS / APPLICATIONS

These results indicate that landscape-scale factors can be associated with general trends of mortality risk from power lines, with eagle use a stronger indicator of risk than power line density. It would be valuable to refine the types of data used to characterize eagle use. Also, the scale of the analysis matters, as do site-level characteristics. More analysis is necessary to determine the scale at which these risk factors may prove to be the most influential. While we were able to identify areas where fatality reduction measures could be most effective, expanding publically available data for both eagle use and fatalities would better inform these kinds of risk analyses.

Questions & Discussion

Q: ***Are the risk factor, land cover and other data you presented publically available?***

A: All of the data that we evaluated as risk factors (landcover, major water features) are agency-generated and publically available. PG&E's eagle fatality data are not.

Q: ***APLIC data indicate that power pole configuration is the best indicator of risk for eagles. Did you consider this factor in PG&E's assessment?***

A: The piece I talked about is for a broad-level landscape assessment (for ECP as a whole), but we also looked at fatality data and how they correspond to transmission v distribution, and also would take into account site-level characteristics in terms of the risks they would present to eagles.

Q: ***Did you correlate mortality with specific types of power lines, e.g., transmission vs. distribution or 69kV vs. 245 kV vs. 345 kV lines? Was there a correlation between different power pole structures and line configurations?***

A: We looked at general trends in proportion of fatalities between transmission vs. distribution (more fatalities result from distribution lines and the disparity between transmission and distribution is more drastic in Golden Eagles). When assessing landscape-scale risk factors, we did not distinguish among pole types.

Q: ***You note that power line density is not a good risk indicator. Did you consider stratifying the power lines into APLIC "raptor safe" v non-retrofitted poles?***

A: We would have liked to be able to stratify, but given we were dealing with 49 million-acre plan area – many millions of poles – without extensive spatial mapping of retrofitted poles, we were not able to do that.

Q: ***Have you considered the influence of confined animal feeding operations on eagle use due to carcass scavenging or an increased prey base?***

A: We did not consider concentrated feeding operations, but that's an interesting point.

Q: ***Given that agricultural areas may have irrigation powered by high-risk power poles, shouldn't agriculture rank as a higher risk habitat type or land use?***

A: We ranked agriculture as a low-use rating. Admittedly, that is a very generalized ranking. There are different types of agriculture with different levels of suitability for eagles. The point about relating power lines and agricultural landscape gets back to importance of site-level characteristics when thinking about eagle risks from power lines.

Q: ***A high proportion (48%) of fatalities occurred in herbaceous landcover, despite this being less than 20% of total landcover. Might that be a function of the increased detectability of eagle carcasses in herbaceous cover?***

A: It could be. Eagles are highly detectable in general. We did find higher-than-expected fatalities occurring in herbaceous cover, and that may be partly a function of greater detectability in that type of landcover.

Q: ***Can you elaborate on methods and reasoning behind your Golden Eagle use classification? Any methods for verification?***

A: We took a fairly general approach to rating use – given the large area covered, we had to rely on literature review to get an idea of potential nest densities across various habitat types and best professional judgment in rating use from high to low. A lot of the research into landscape-scale eagle use indicators that is ongoing could benefit these types of analyses in the future.

Daytime habitat selection by resident Golden Eagles in southern Idaho, USA

Presenter: Chad LeBeau, Western EcoSystems Technology, Inc.

[presentation]

Co-Authors: Ryan M. Nielson, Eric C. Hallingstad, David P. Young (WEST, Inc.)

PROBLEM / RESEARCH NEED

Energy and other types of development are increasing across the western range of Golden Eagles (*Aquila chrysaetos*), and both private and governmental agencies have expressed concern about indirect and direct impacts to this species. To facilitate sustainable anthropogenic development and reduce risk to Golden Eagles, the U.S. Fish and Wildlife Service (the Service) has set forth guidelines to assist developers in project planning and siting actions. A major component of impact assessments is documenting Golden Eagle spatial use near a project site before development.

There are a variety of ways to characterize use, including nest surveys and ground-based observational surveys. The latter are subject to spatial and logistical constraints, particularly in rugged and remote locations, and such factors as weather, time of day, access, and observation bias may constrain the usefulness of the data for assessing risk. Another approach is to develop resource selection functions (RSF), which compare the set of resources animals use with what is available on a given landscape. RSFs have been developed for many different species, and can be used to identify high- and low-use areas over a project area.

Objectives

The goal of this project was to develop unbiased estimates of habitat selection (spatial use) in and near a proposed project area. Specifically, our objectives were to:

- Inventory Golden Eagle nests and territories within the study area;
- Generate robust RSFs to predict Golden Eagle habitat selection across the study area (Southern Idaho and Northern Nevada);
- Demonstrate how predictions of Golden Eagle habitat selection may be used to delineate high use areas or areas of potentially higher risk in land management planning.

APPROACH

Our approach combined helicopter nest surveys and telemetry data to track the movement of four resident Golden Eagles. In the early spring of 2011, before egg-laying, we captured and tagged two adult male and two adult female Golden Eagles – each from a different territory within the approximately 213,180 ha (2,132 km^2) study area. GPS data were collected from two hours after sunrise to two hours before sunset, when Golden Eagles are most active. Locations outside the study area (8% of all location data) were excluded from RSF modeling.

Resource Selection Function (RSF) Modeling

We developed separate RSFs for each of three biologically meaningful seasons in 2011: spring (late February/early March to the end of June); summer (July 1-Sept. 15); and fall (Sept. 16-Nov. 1). Each seasonal analysis of daytime habitat selection was conducted in multiple steps (slide #12):

1. Develop RSF for each individual within its home range (available vs. used locations).
2. Combine the data for all four birds.
3. Re-estimate the RSFs (accounting for variability in habitat selection among individuals) and predict use across the study area.
4. Use "leave one out" K-fold method to validate predictions (slide #32).

The study area is characterized by large canyons, steep canyon walls, and sagebrush habitat. Landscape and vegetation features used in the habitat selection model were:

- Landscape: elevation, mean elevation, slope, mean slope, ruggedness (rocky outcrops, perching opportunities), mean ruggedness, radiation (includes sun angle and shadows cast by surrounding topography), and rim edge
- Vegetation: *Normalized Difference Vegetation Index (NDVI)*, *Soil-adjusted Vegetation Index (SAVI)*, wetness, brightness, greenness, shrub, nest, lek

We incorporated these covariates into a binary logistic regression equation in a use-availability framework with a maximized likelihood to estimate an exponential RSF predicting the relative probability of Golden Eagle habitat selection. (Slides 29-31 give the final RSF for each eagle for each season.)

Nest Surveys

Nest surveys were conducted by helicopter from April 18 through April 26, 2011, when Golden Eagles were expected to be incubating eggs or brooding nestlings. Nests were designated as either occupied (if being used for breeding in the current year) or unoccupied if the nest was not selected by Golden Eagles for use in the current nesting season. There were 32 occupied territories which appeared evenly distributed throughout the study area.

FINDINGS

The final RSFs estimated that relative probability of selection by Golden Eagles was highest closer to nests and over moderately rugged terrain. Moderate to higher levels of brightness (a measure of non-vegetated habitats) and slope were also seasonally important. The RSFs were used to generate predicted levels-of-use maps for each season (slide #22-23). These maps showed that eagle movement is more highly concentrated at higher elevations in the spring than in the summer or fall.

Model validation indicated that the models reliably predicted Golden Eagle use within the study area. Slide #32 details the validation process; see slide #24 for Spearman's rank correlation coefficients. Higher correlations indicate the data and process used to create the final predictive map was robust to among-animal variability in habitat use.

CONCLUSIONS / APPLICATIONS

This is the first study estimating Golden Eagle habitat selection based on a combination of GPS and Golden Eagle territory nesting data.

The process we developed may be used to improve our understanding of Golden Eagle habitat selection and to quantitatively measure risk, identifying potential areas of conflict prior to development and quantifying potential impacts associated with habitat changes in before and after development scenarios. The same methods may provide valuable information about non-resident vs. resident vs. transient eagles.

In future research it would be useful to discriminate between perching and flying habitat resource selections.

Questions & Discussion

Q: You used rank correlation coefficients to "validate" models. How many habitat categories were involved in correlation? Why not use Pearson's?

A: We considered 20 bins in our ranking process. We looked at how many use locations were within each of those 20 bins, and then ranked them using Spearman's correlation. We considered Pearson's which provided similar results as the Spearman's.

Q: *Explain "brightness" co-variate – how derived, and why is it important to eagles you studied?*

A: The brightness covariate was developed from a normalized differential vegetation index (NDVI). It shows an area of bare ground, a dry area – typically a rocky or barren landscape.

Q: ***How does the eagle use model you are developing compare with eagle collision risk models?***

A: Our model is looking at habitat selection, not necessarily collision risk. It's not taking into account other collision factors. For example, we did not distinguish flying locations or perch locations.

Modeling risk from wind power to breeding and migrating Golden Eagles near the Gulf of St. Lawrence, Québec, Canada

Presenter: Tricia A. Miller, *West Virginia University*

[presentation]

Co-Authors: Jérôme Lemaître (Ministère des Forêts, de la Faune et des Parcs, Québec); David Brandes – Professor, Lafayette College); Michael Lanzone (Cellular Tracking Technologies); Jeff Cooper (Virginia Department of Game and Inland Fisheries); Adam Duerr (West Virginia University); Todd Katzner (U.S. Geological Survey)

PROBLEM / RESEARCH NEED

Wind turbines are a known source of mortality to birds and certain turbines have caused significant mortality of local bird populations. Significant wind power development is occurring in Québec on the Gaspe Peninsula and along the north shore of the Gulf of St. Lawrence. This development is coincident with the southernmost breeding population of Golden Eagles (*Aquila chrysaetos*) in eastern North America and with concentrated migratory movements of northern eagles. Because the Gulf of St. Lawrence is a barrier to migration, eagles concentrate along shores during migration (south shore in spring and north shore in fall), before crossing or going around the Gulf.

The landscape near the Gulf of St. Lawrence in the province of Quebec is heavily forested and rugged – quite different from the western U.S. Often when we talk about risk we equate it to mortality. In this case we are thinking about risk in terms of indirect as well as direct impacts – "decreased fitness" would be a better term.

Objectives

The objectives of this research were to assess risk to eagles and to improve wind turbine siting to reduce both the direct and indirect impacts on Golden Eagles.

APPROACH

We fitted Golden Eagles with GSM and satellite telemetry units in 2006-2014 from NW Alabama to the Gaspe Peninsula and tracked 24 birds over up to eight years through the study area. The telemetry data were used to develop spatially-explicit eagle resource selection functions (RSFs) for the study area (slide #9). Summering areas may be important because it is the southernmost breeding population. Wintering areas may become more if birds shift their winter range northward due to climate change.

To identify areas of potential conflict, we compared these eagle models to turbine habitat suitability models, as well as to 1,145 proposed and existing turbine developments. (We were able to use USGS data for wind turbines in Maine, but had to manually locate and digitize turbine locations for Canada.)

For 11 eagles tracked during summers and 24 eagles tracked during fall migration, we mapped use (defined as flight locations in the risk zone <150 m AGL) v. available random points. Turbine locations were similarly mapped. We then looked at eight environmental covariates that potentially influence flight behavior or turbine locations:

- Elevation
- Eastness
- Northness
- Slope
- % Tree Cover
- Distance to Gulf
- Landform
- Updraft

We then calculated logistic generalized estimating equations (GEEs) for eagles during each season and for wind turbines, and then calculated RSFs to create spatial models.

In addition to the RSF models, we also looked at flight altitudes and the use of different landforms, to see how eagle behavior differs among seasons, in ways that may be relevant to risk with respect to wind energy facilities.

<u>FINDINGS</u>

Preliminary results indicate that there are seasonal differences in movement characteristics of eagles. Eagles generally are flying at higher altitudes (and higher AGL) during spring and summer as compared with fall and winter. They utilize land types similarly across seasons, but they are using broad flat areas more during migratory seasons – whereas, during summer, eagles tend to avoid broad flat areas, and select high updraft areas along northwest and southwest-facing slopes. (See slides #23-24; the Wald value indicates how important the characteristic is to the model.)

Turbines are built almost exclusively on three landform types – mountains/ridge tops, flat ridge tops, and broad flat areas – all of which are used by eagles flying at low altitudes. However, within individual developments, not all turbines present the same level of risk. Turbines located near areas with high updrafts, especially near NW and SW-facing slopes, pose a risk to summering eagles and fall migrants. Ridge-top developments pose the greatest risk to fall migrants. Broad flat areas appear to pose a lower risk to eagles during summer.

CONCLUSIONS / APPLICATIONS

It is possible to make site specific recommendations for reducing risk by modifying siting of individual turbines. Next steps are to combine eagle and turbine models to create spatial models that can be used to guide development in Québec, and to model risk in other regions, especially California.

Questions & Discussion

Q: ***Are there any fatality data for your study area that could be used to test correlation between modelled risk and mortality?***

A: Not that I know of.

Q: ***How do you deal with spatial auto-correlation in collar data?***

A: The models can deal with that by including a correlation structure in the models. The GEEs deal with non-independence of each cluster or individual and then you can set a correlation structure (AR1) to deal with auto-correlation.

Eagles and Wind Energy: Demographic Impacts, Nest Disturbance, and Fatality Prediction

Origins of eagles killed at the Altamont Pass Wind Resource Area

Presenter: Todd Katzner, U.S. Geological Survey, West Virginia University (WVU), U.S. Forest Service

Co-Authors: Adam Duerr, Tricia Miller, Melissa Braham (WVU); David Nelson (University of Maryland); Peter Bloom (Western Foundation of Vertebrate Zoology), Jackie Doyle, Andrew DeWoody (Purdue)

Abstract: Golden eagles (Aquila chrysaetos) of unknown origin are killed every year at the Altamont Pass Wind Resource Area (APWRA). We used a combination of population genetics and stable isotopes (δD, δ13C, δ15N) to evaluate the origins of >50 eagles killed at turbines at the APWRA. Preliminary interpretation of δ13C and δ15N results were consistent with those expected for apex predators eating primarily terrestrial prey. Stable hydrogen isotopes (δD) suggested that ~80% likely grew feathers in a region that includes the APWRA. Of the remaining eagles, feathers ~10% may have been grown elsewhere and feathers from the remaining 10% were highly likely to have grown elsewhere. Genetic (microsatellite) data tested the null hypothesis that all eagles were from a single, panmictic population and did not confirm the alternative that the 80% “resident” eagles formed one interbreeding genetic population to the exclusion of the 20% “nonresident” eagles. Genetic and isotope data are a useful pair of tools for resolving origins of eagle carcasses from wind turbines. In this case preliminary results suggest that 10-20% of the eagles killed at APWRA spend at least part of the year outside of California. Thus the demographic impact of eagle mortality at this site may extend well beyond California.

To disturb or not to disturb: the difficulty in assessing Golden Eagle nest disturbance at wind energy facilities

Presenter: Julia Garvin, *Tetra Tech, Inc.*

[presentation]

Co-Authors: Laura Nagy (Environmental and Permitting Services, DNV GL-Energy)

PROBLEM / RESEARCH NEED

The Bald and Golden Eagle Protection Act (BGEPA) was amended in 2009 to allow for both lethal and non-lethal take permits. Disturbance to Golden Eagles is considered a form of take, and, as such, is prohibited under BGEPA. The U.S. Fish and Wildlife Service (the Service) is evaluating Golden Eagle nest abandonment, a form of disturbance, as a potential impact of wind energy facilities. The Service's Eagle Conservation Plan Guidance (ECPG) does not provide detailed criteria for assessing disturbance, but the Final Eagle Permit Rule indicates that the Service will interpret the absence of nesting activity during up to three years of post-construction monitoring at recently used nests as evidence that disturbance – in this case nest abandonment – rising to the level of take has occurred.

The problem is that there is substantial uncertainty as to whether and how a wind facility might cause nest abandonment. Although the Service frequently uses the term "nest" and "territory" interchangeably, the term "territory" is the more significant unit, biologically speaking. Abandonment of a given Golden Eagle territory is difficult to determine because of several factors.

1. Breeding pairs do not breed every year, so it is hard to determine what it means that a nest is not being used. Data on confounding factors are rarely collected.
2. Territories often have multiple nests – as many as 16 nests have been found in a single territory – and nests within a single territory can be quite close together or up to a mile apart.
3. It is difficult to determine territory boundaries without marking individual eagles, which itself requires a permit and considerable expense.

Additionally, the nature of wind energy development presents challenges to studying territory abandonment in an empirical manner (i.e., controlled experiment).

Objectives

The objective of this study was to evaluate available data on pre- and post-construction nest status and territory status variables at existing wind facilities to determine whether there is evidence of an effect of wind energy facilities on Golden Eagle territory abandonment.

APPROACH

A review of the literature suggests that Golden Eagles are more susceptible to anthropogenic disturbance than are Bald Eagles. In reviewing government management documents, peer-reviewed scientific literature, and industry reports, we sought to identify operational wind projects with post-construction eagle nest survey data as well as pre-construction nest survey data if available. We found ten projects that met the basic criteria, but only eight of these had pre- as well as post-construction data.

We took a conservative approach, pooling territories for a given project and taking results at face value. Studies varied in their methods; some had been conducted prior to the ECPG issuance, some since then; survey effort and coverage varied, as did definitions of nest status. Data on confounding factors such as weather or prey abundance were rare.

FINDINGS

For each of the projects, differences in nest and territory status were ranked as positive, negative, or neutral, and categorized as to whether or not the effect of the wind facility could be isolated. A simplified decision tree (slide #9) gave us three possible outcomes:

1. No evidence of territory abandonment
2. Evidence of territory abandonment but unable to isolate wind farm as cause
3. Evidence of territory abandonment as a result of the wind farm

Slide #10 summarizes the evidence from the ten projects (across seven states) with post-construction data. Most project areas covered parts or all of 1-5 territories; Altamont was an outlier with 58 territories. Post-construction monitoring ranged from 1-4 years. The proportion of territories occupied post-construction ranged from 67% to 100%.

Seven of the ten projects showed no evidence of territory abandonment. The remaining three were projects that had territories occupied pre-construction that were not occupied post-construction. All three of these projects had both pre- and post-construction data, allowing further analysis. Evidence of territory abandonment was not conclusive, and confounding factors prevented isolating the wind farm as the cause:

- One of the projects had multiple years of non-occupancy before as well as after construction
- Two of the projects did not allow for clear territory definitions, making it difficult to determine whether unoccupied nests constituted an abandoned territory, or were simply an unoccupied part of a territory still being used.

CONCLUSIONS / APPLICATIONS

It is very difficult to prove that abandonment occurred, or that it occurred solely in response to a wind farm. The regulatory implications of our results suggest that the best scientific information available may be insufficient to isolate wind farms as the cause of territory abandonment. Given this uncertainty, the mitigation penalty for disturbance is quite heavy. The Service equates permanent abandonment of a Golden Eagle territory to the take of 4.26 Golden Eagles per year, or 8 Bald Eagles per year in the case of a permanently abandoned Bald Eagle territory. The Service may need to re-evaluate some of its assumptions relative to disturbance in the ECPG, and to consider alternate methods to assess disturbance rising to the level of take.

Future research needs to be conducted on a broader scale than a single wind energy project, using Before-After Control-Impact (BACI) studies of nest disturbance to investigate the influence of an existing disturbance regime and potentially confounding factors. Longer-term datasets of nest occupancy, particularly post-construction, would also help in determining whether abandonment is occurring as a result of wind farms.

Questions & Discussion

Q: ***If a nest is abandoned and another nest shows up in the same territory during the same breeding season, can you conclude that territory was not abandoned?*** *(Any evidence to suggest this ever happens?)*

A: If there is a nest occupied in the territory – no matter where it is or which breeding pair is occupying it – we consider the territory to be occupied. I have not seen any data on a breeding pair abandoning one nest for another during the same season.

Q: ***Is there information on other sources of disturbance resulting in Golden Eagle nest abandonment?***

A: Other anthropogenic sources of disturbance include hikers, trail runners, off-road vehicles, etc.

Q: ***How can abandonment of one Golden Eagle nest result in annual loss of 4.26 Golden Eagles (or abandonment of a Bald Eagle nest result in the annual loss of eight Bald Eagles)?***

A: In the final environmental assessment (FEA), the permanent loss of a *territory* is equated to eight Bald Eagles based on results of demographic population modeling.

Q: ***What is the highest number of chicks observed in a single Bald or Golden Eagle nest?***

A: Incidences of four eaglets in Eastern Bald Eagle nests; up to three in Golden Eagle nests.

Q: ***How many years of pre and post-construction eagle surveys would be needed to determine whether a nest had been permanently disturbed or provide evidence of territory abandonment?***

A: The Service states that up to three years of post-construction data will be used to make this determination.

Q: ***Would you ever be able to eliminate confounding factors?***

A: No, but we could get information about some of the most important confounding factors.

Q: ***Did you look at nesting success/failure in addition to occupancy?***

A: Not for this study. Typical eagle nest monitoring studies at wind facilities do not necessarily measure nest success. Peer-reviewed research tends to focus on nest success, but it is more challenging to determine nest occupancy.

Application of eagle fatality prediction modeling to quantify a reduction in risk based on the implementation of avoidance/minimization measures and experimental advanced conservation practices

Presenter: Kristen Adachi, Western EcoSystems Technologies, Inc.

Co-Authors: Wally Erickson, Kenton Taylor, Todd Mattson, Kimberly Bay, Rhett Good (WEST, Inc.)

PROBLEM / RESEARCH NEED

Estimating the level of Golden Eagle fatalities at proposed wind energy projects has become an integral part of the U.S. Fish and Wildlife Service (Service) programmatic eagle take permit process. A model that utilizes a Bayesian framework has been developed by the USFWS that includes information on Golden Eagle use and mortality at existing wind projects as a starting point or "best guess" of anticipated impacts (i.e., the Bayesian prior distribution) to eagles at a wind project. Site-specific data on eagle use are combined with the prior information to estimate fatalities for a proposed project:

> Predictions of annual eagle mortality (F) = $\mathcal{E}$ (Expansion Factor) x λ (Rate of Eagle Exposure) x C (Probability that eagle exposure results in a collision with a turbine)

As presented in the USFWS Eagle Conservation Plan Guidance (ECPG), the collision probability prior distribution includes data from older wind facilities and does not reflect the potential lower risks posed by modern wind technology.

Objectives

Update the USFWS model based on publicly available studies from 24 modern operating facilities.

APPROACH

We used more recent data and a larger data set from 24 modern facilities (excluding data on older style turbines from Altamont, San Gorgonio, and Tehachapi) to update the collision probability prior distributions.

For a single site, the posterior distribution becomes the prior distribution for next iteration of the collision risk model to update model. We estimated the number of fatalities from post-construction monitoring using Smallwood (2007) and also estimated the number of exposure events that did not result in a fatality using Whitfield (2009).

Prior distributions were constructed using eagle observation data, with the assumption that an eagle observation was equivalent to the "eagle minute" recommended in the 2011 ECPG. We found, however, that the length of eagle observations averages 3.2 minutes for Golden Eagles, and 4.8 minutes for Bald Eagles from an internal WEST dataset. Equating 3- to 5-minute eagle observations with one "eagle minute" when calculating the probability of collision per minute of exposure most likely results in conservative predictions – that is, a higher rate of fatalities per unit time of exposure to the turbines.

We also updated fatality predictions with updated searcher efficiency and carcass persistence for eagles.

FINDINGS

Using the updated collision probability prior distributions, predicted fatalities are approximately one-half the estimates using the original distribution.

We also were able to demonstrate how to quantify a reduction in collision risk through the implementation of various avoidance/minimization measures (e.g., fewer turbines, reduced daylight hours of operation) and experimental Advanced Conservation Practices.

CONCLUSIONS / APPLICATIONS

The ECPG suggests updating collision probability with additional data as they become available. This analysis confirms the value of doing so. We recommend adding more publically available data to refine the collision prior update.

Questions & Discussion

Q: ***Has the Service accepted the alternative collision probabilities for fatality modeling at a prospective wind farm? If not, what reason given?***

A: The Service has done an initial review of our work, but they are waiting for it to be published before commenting/responding.

Q: ***How could you minimize impact by reducing turbine blade size?***

A: That was for a proposed facility – idea was that different turbine type might be chosen.

Q: ***Is there any correction factor in the eagle exposure metric to account for area visible from the point-count location? (Thinking of differences between open landscapes such as are common in the west and forested ridgelines of the northeastern U.S.)***

A: We are assuming a certain viewshed from the point-count location. If a portion is not visible, it doesn't get counted, but we try to select point count locations where most area within the viewshed is visible.

Assessing Risk to Birds and Bats: High Tech Detection, Classification, and Survey Techniques

Using remote acoustic and thermal sensing detectors to reduce mortality at onshore and offshore wind facilities

Presenter: Greg Forcey, Normandeau Associates, Inc.

[presentation]

Principal Author: Julia Robinson Willmott (Normandeau Associations, Inc.)
Co-Author: Christine L. Sutter (Normandeau Associates, Inc.)

PROBLEM / RESEARCH NEED

Current developments and plans to make extensive use of onshore and offshore wind resources in both Europe and the U.S. have increased awareness of wind turbines' potential to adversely impact birds and bats. Risk assessment studies of bats and migratory birds in relation to planned wind farms are routinely based on non-continuous surveys at different times of the year. The lack of continuous sampling limits the temporal range of bird and bat abundance and activity data to specific times throughout the year.

Objectives

In 2009, the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) funded the development of a system that combines thermal imaging and acoustic and ultrasound sensors. The goal was to create a risk management tool that could be used throughout the life-cycle of a project:

- Pre-construction – for site screening and relative risk assessment; understanding spatial and temporal patterns of use
- Post-construction – for operational monitoring and "smart curtailment" strategies (e.g., shut down operation only when activity is likely occurring near turbines); mortality monitoring triggered by high activity events

APPROACH

The system was installed beneath a coastal wind turbine at UD Lewes, Delaware, to test its site screening capabilities. From July 18 to August 9, 2011, the system collected 0.88 terabytes (TB) of audio data, 13.2 TB of thermographic data, and 6 gigabytes (GB) of ultrasound data.

A total of 641 bat passes were detected from five of the eight species of bats known to be resident in Delaware. Neither of the two species listed as state endangered were found to occur at the site. The most common bats detected were the eastern red and silver-haired bats.

Extended data collection allowed us to model bat activity as a function of weather variables. Eastern red bat activity increased with increasing barometric pressure. Silver-haired bat activity decreased with increasing wind speed.

For the next phase of testing (December 6, 2011 to April 3, 2012) we deployed the system at the Frying Pan Shoals Light Tower (FPSLT), an 80-foot platform located 29 miles southeast off the coast of North Carolina. For this installation we built weather-proof housing for the system, including a wiper system for the camera lenses. No bats were detected at the offshore location, but we were able to identify 33 species of songbirds migrating over the ocean, and collect data on abundance, flight altitude, flight direction, and flight velocity on 1,477 individuals.

FINDINGS

Data gathered by the system show clear patterns of bat and migrant bird occurrence, which can be used to predict activity on a species-specific basis. For example, eastern red bat activity increased with increasing barometric pressure, and silver-haired bat activity increased with increasing wind speed and decreased with increasing temperature.

At the offshore testing site, only birds (no bats) were detected. A total of 2,640 songbird calls were recorded, representing at least 33 species. The species composition reflected trans-Atlantic migrants that winter in the Caribbean and northern South America, including Amazonia:

- Cape May and Black-throated Blue Warblers – known to winter primarily in the Caribbean and presumed to migrate mostly across the northwestern North Atlantic
- Gray-cheeked Thrush, Blackpoll Warbler, and Bobolink – known to winter east of the Andes in South America
- Unexpected species were short-range migrants – American Pipit, Chipping Sparrow, Dark-eyed Junco.

We looked at total abundance and total daily abundance by month (diurnal and nocturnal). Abundance data were corrected for the system's detection success and the amount of time the system was running. April and October showed peak density of migrant songbirds in the offshore environment, with high counts of several passerine species, such as Cape May Warbler, Northern Parula, Palm Warbler and Yellow-rumped Warbler.

Thermographic data were used to compare passerines with non-passerines (defined by size of bird). Non-passerines flew lower, on average. Acoustic data gave some species-specifc data. Both acoustic and thermographic data show birds occurred consistently through a range of wind speeds up until approximately 10 km per hour, when abundance declined. Average flight altitude was fairly consistent throughout the day, with somewhat higher altitudes between 8 am and 12 pm. We saw no relationship between flight altitude and wind speed.

Thermographic data were also useful for understanding the relationship between flight speed and direction for passerines (slide #17) and non-passerines (slide #18). Many of the non-passerines were not migrating birds but rather local species using the platform as a roosting location.

CONCLUSIONS / APPLICATIONS

Abundance data from this remote acoustic and thermal sensing device can be modeled as a function of weather variables to better understand the influence they have on activity levels and thus potential exposure to wind turbines. Activity models can be used to predict activity of select species which can inform curtailment decisions thus reducing mortality of the species of interest.

The Electric Power Research Institute (EPRI) is developing such a “Smart Shutdown” tool – an acoustic-based Supervisory Control and Data Acquisition (SCADA) integrated turbine management system that can process data streams in real or near-real time. With an industrial-grade interface between the models and the facilities’ SCADA system, the objective is to reduce bat mortality while minimizing operational impacts on the facility.

Questions & Discussion

Q: ***There is evidence that bats occur offshore – did you try to look at why there were no bats observed in your study?***

A: The bat microphone was operational only during the winter and spring migration periods, so any bats occurring in the summer or fall would not have been detected. It is unknown why no detections occurred in the spring. Bats are most likely to be found offshore during the fall migration period when inclement weather forces them off their normal migration paths (e.g., Mackiewicz and Backus 1956; Carter 1950). Although bats have been encountered this far offshore and away from any terrestrial habitat, data show that it is unlikely that they occur at remote stations like FPSLT with any regularity. They are more likely to be found near offshore islets and outcrops with some semblance of roosting and/or foraging habitat suitable to the migratory species.

Q: ***How did you get velocity from thermal video data for onshore bat data set?***

A: Two cameras were used simultaneously, which provided stereo imagery allowing accurate calculation of height and speed. This process is automated in our system.

Q: ***What are the zones of detection for the bird and bat microphones?***

A: They vary. The ultrasonic detectors’ maximum range is from 50-80 meters depending on the conditions. When mounted upon a turbine, two ultrasonic microphones would be used. With the acoustic microphones, some birds were detected up to 300m away from the microphone. We did a study to validate the zone of detection using a helium balloon with an attached speaker. Calls were recorded at various heights to determine the zones of detection.

Q: ***What is the maximum altitude your equipment could detect a bird?***

A: That depends on the size of the bird and the resolution of the camera. We detected a large bird at 250 m above sea level. As resolution of thermographic cameras improves, we should be able to detect birds further away.

Q: ***How did you determine flight altitude?***

A: Flight altitude was determined from the camera information. Two cameras were used which provided stereo imagery allowing accurate calculation of flight height and speed. This process is automated in our system.

Q: ***Were there any observations in July?***

A: Yes. We excluded July data from our results because the system was operational only for six days during July.

Q: ***How did you determine whether a target was a gull, tern, skimmer v passerine?***

A: We primarily used body shape and size to determine the type of target. (Gulls, terns and skimmers have long wings.) We had to rely on acoustic data to get more species specific identification. We classified birds that were <20cm as a passerine and >30cm in size as a non-passerine.

Q: ***How did you account for differences in detection probability related to such things as species and altitude, for both acoustics and thermal sensors?***

A: The detection system for the thermographic cameras was automated. In order to account for the detection success, we sampled about 10% of the images by hand, to actually look for targets. Once we knew how many real birds or targets were in the images, and we knew how many the automated system had detected, we could account for the detection probability and correct the abundance. We did not account for differences in detection probability among species – therefore our data only present an index of abundance and cannot used to calculate density estimates.

<u>Questions submitted but not addressed during session:</u>

Q: ***Will the integration of the bird detection system be based on a data interface that is common in the utility or wind industry?***

A: Yes we are using a SCADA interface which is common in the utility industry.

Q: ***How do you resolve bird size vs. distance from video analysis?***

A: With the two cameras operating in stereo, we can automatically calculate flight height using the known location of the image in each camera and trigonometry. We can then measure the size of the animal depending on how many pixels the animal occupies at that height.

Q: ***How did you determine flight altitudes using acoustic detectors? For what proportion of detections were you able to determine flight altitudes, and what is your detection distance of acoustic detectors?***

A: Flight was not determined by acoustic detectors; it was determined by stereo thermographic cameras. Flight altitudes were calculated for 1,477 thermographic detections, but with the thermographic detector alone we could only classify most targets into broad categories such as gull, tern, etc. with the exception of shape-evident birds such as the frigate bird. Acoustic information provided species-specific identification. Detection distance for acoustic detectors was up to 300 m depending on the species and call frequency; 50-80 m was the maximum distance for the ultrasonic detectors.

Classification of birds and bats and their flight paths from thermal imagery

Presenter: Valerie Cullinan, Pacific Northwest National Laboratory

[presentation]

Co-Authors: Shari Matzner, Corey Duberstein (Pacific Northwest National Laboratory)

PROBLEM / RESEARCH NEED

Classification of birds and bats that use areas planned for offshore wind farms and inference of their behavior is essential to evaluating the potential effects of offshore wind development. Flight paths associated with foraging behavior could indicate critical resources in an area and a potentially higher risk from development. Thermal infrared (IR) cameras can enhance monitoring programs at a reasonable cost and collect data during inclement weather and at night. However, human analysis of the video is time consuming and an automated process is desirable.

Objectives

Our overall objective was to develop software for a single thermal camera to automate the processing of thermal video and the detection, count, and identification of birds and bats. Specific project objectives were to:

- Provide data for site-scale risk assessment to birds and bats from offshore wind farm development.
- Develop an annotated library for target detection, classification, and validation.
- Develop a framework for model building classification of flight paths and of targets.

APPROACH

The first step was to develop an annotated library of flight tracks for use in target detection, classification and validation. Five thermal video segments, each 5 minutes in length, were taken from a dock, looking up into wooded areas along the shoreline. An observer looking through a telescope recorded observations within the same field of view as that of the thermal video camera. A second person reviewed both the thermal video and the observer's notes.

We recorded a total of 160 tracks, primarily in four taxa: gulls (73), terns (4), swallows (31), and bats (8). For each time point while the target appears in the field of view, the pixel "blob" can be assigned an x and y coordinate as well as a direction of movement and change in direction at time *t*. (The track detection algorithm is described in greater detail in Shari Matzner's presentation.) We developed a discriminant model to classify five types of flight paths that mimic observed flight behavior, and applied the model to flight paths extracted from the thermal video:

1. Linear - fly through
2. Quadratic - smooth change in direction
3. Sine wave - sinuous fly through
4. Angled - sharp change in direction
5. Turnaround - sinuous feeding

Circling, hovering, and plunging dive behavior by some pelagic species indicates foraging activity and may resemble quadratic or angled shaped tracks. A zig-zag pattern of flight has been subjectively used to distinguish bats from birds during nocturnal surveys and would be expected to resemble complex turnaround or sine-shaped tracks. Linear flight behavior is characteristic of direct flights to and from nesting or foraging areas.

For each type of track, we created a database of theoretical types (30 of each of the 5 types). We added Gaussian noise, then smoothed the tracks and calculated changes in directions and calculated descriptive statistics on change in direction. There was a high level of similarity between the modeled angled, linear, and quadratic (ALQ) tracks, so we removed highly correlated variables, conducting a two-part forward-stepping discriminant analysis. Model development was conducted with 52 of the theoretical tracks, and the 98 remaining tracks were used for model validation.

FINDINGS

The first model was able to correctly classify 100% of the ALQ tracks, 75% of the sine wave tracks, and 83% of the turnaround tracks. The second model was able to correctly classify 100% of the quadratic tracks, 83% of the linear tracks, and 63% of the angled tracks.

The models were then applied to flight path data (n = 64 tracks) extracted from the five annotated video clips. Forty-one percent of the flight paths were classified in agreement with the observer. The number of tracks in agreement increased to 59% using the combined ALQ category and increased again to 62% when only two categories, ALQ and the combined sine wave and turnaround paths, were used. Censoring small changes in direction ("jitter") increased track classification agreement to 73%. Errors in target classification associated with resolution of the track were reduced by using the target's size-to-speed ratio to estimate the probability of the target being near to the camera.

Cross-validation was done by creating five resampled data sets. Classification of 46 bat, swallow, gull, and tern tracks were 82% accurate on average, based on this jackknife cross-validation. Bats and terns (n = 4 and 2, respectively) were 94% and 91% correct; however, the variance associated with the tracks from these targets is poorly estimated. Gulls and swallows (n ≥ 18) had on average 73% and 85% correct classification, respectively.

CONCLUSIONS / APPLICATIONS

We are working on an estimate of the wing beat frequency and flap-glide pattern (see Duberstein presentation). Our ability to correctly classify tracks and the associated target could be enhanced by using dual (thermal and radar) sensors to give us the distance to the targets from the camera. Next steps include building a larger annotated library, incorporating priors based on the target's probability of occurrence for specific sites.

Questions & Discussion

Q: ***The bats you observed were all along the shoreline – none offshore?***

A: Yes. I am not certain that we will find bats offshore on the Pacific coast. We are unaware of any observations.

Q: ***How would a more effective estimate of distance (as with a stereoscopic camera) improve your ability to classify the targets?***

A: If I had distance, I would be able to determine body size (how large it would appear at a given distance). For an annotated data set where I know the organism; know the distance, and know the body size – I can categorize birds by body size class and know from that category of birds which species it is more likely to be; we can also add greater certainty by looking at the wingbeat frequencies.

Q: ***Are there bird species that would be likely to want to roost on operating wind turbines offshore? Can we expect anything radically different from what has been observed offshore in the UK?***

A: Swallows are less likely to be found offshore of the Pacific coast, and I do not expect to see bats offshore in the Pacific, but certainly gulls and terns. Using high definition aerial photography, we'll have an idea of what the distribution of species are on both sides of the coast. That will allow us to build probability models of which species are at risk.

Q: ***Do you think discrimination of flight tracks alone will allow you to discriminate species groups?***

A: No, you have to look at the pixel body blob information. We were not able to do the distance determination, and further, ghosting in the thermal image made it hard to gauge the relative size of the target's body using the automated track detection algorithm.

Shipboard vs. high definition video aerial survey techniques: a comparison in the mid-Atlantic

Presenter: Kate Williams, Biodiversity Research Institute

[presentation]

Co-Authors: Iain Stenhouse, Evan Adams, Emily Connelly, Melissa Duron, Andrew Gilbert (Biodiversity Research Institute)

PROBLEM / RESEARCH NEED

Aerial surveys using a high definition video platform are a recent methodological approach for the United States, though they have become common practice for offshore wind energy development in Europe. What role might the new technology play in surveying avian species at potential offshore wind resource areas, and how will aerial data compare with or complement data from traditional boat survey methods?

Objectives

We specifically sought to compare the results of boat surveys with aerial videography as a method for species identification and abundance estimation, and also to determine the extent to which boat survey results may be biased by disturbance or attraction to the vessel.

APPROACH

As part of a three-year study of wildlife distributions and abundance on the mid-Atlantic Continental Shelf, we conducted a comparison study of ship-based and high definition video aerial surveys between 5.5 and 85 km from the coast of Virginia in March of 2013.

- Boat surveys were conducted from a 55' charter fishing vessel covering two parallel transects at 10 knots per hour. One observer and one recorder/observer identified and recorded animals sighted at a distance of up to 800-1000 m from the vessel. (Records included species identification, distance, angle, and animal behavior.)
- Digital aerial surveys were conducted from a plane flying back and forth six times over the same transect being covered by the boat, at an altitude of 610 m above sea level and a speed of 135 knots. Four belly-mounted cameras captured video along parallel 50-m wide transects corresponding to the path of the boat. Video was recorded at 8 frames

per second at 2 cm ground spatial resolution, and GPS coordinates were captured for each video frame.

Species identification rates were compared for auks (Alcidae), ducks/scoters (Anatidae), loons (Gaviidae), gulls/terns (Laridae), and gannets (Sulidae), as well as unidentified birds. We also looked at the proportion of animals that were identified to species vs. family group (e.g., 'Common Loon' vs. 'unidentified loon').

Transects were divided into segments for analysis, and survey data were used to estimate segment-level abundance for the most common species groups. Boat data were modeled to correct for detection bias caused by varying distance of animals from the vessel. It is unclear whether there is a variable like distance that affects digital survey abundance estimates, so the six aerial replicates were simply bootstrapped to provide mean estimates of number of individuals per transect segment. A separate generalized linear mixed model was used to examine the aerial survey replicates to detect potential disturbance by the survey vessel as it passed through the survey area.

FINDINGS

There were substantial differences between the survey methods in terms of identification to species level, though identification rates by family were correlated between survey methods. All individuals observed in boat surveys were identified to the family level, and boat surveys were much better at identifying loons, gulls, and terns to species. However, digital aerial surveys were better at identifying scoters to species, and Northern Gannets were equally identifiable in both survey methods. Gannets were not significantly disturbed by the survey vessel, but 21% fewer scoters were observed in transect segments that had been recently disturbed by the boat. It is unclear whether this disturbance caused bias in counts of scoters from the survey vessel, but it probably did play a role in the poor species identification rates for this species group.

Controlling for transect strip width, in most cases modeled population size estimates using boat data were higher than bootstrapped aerial estimates for the same locations. The geographic distribution of birds (by transect segment) was well correlated between survey methods for scoters, but not for gannets. The aerial transect strip width was narrower than that for the boat, and there was also less opportunity to observe animals during the very brief time the digital survey plane passed over an area. To offset this reduced availability, high definition video aerial surveys are generally flown at higher transect densities than was conducted in this study. At the transect spacing of the boat, however, it seems likely that aerial surveys were simply inconsistent at observing highly mobile species, such as Northern gannets, between replicates. This type of availability bias was likely less of an issue for scoters, which were observed in large, more geographically stable aggregations.

CONCLUSIONS / APPLICATIONS

In this study, we examined the biases, efficiency, and utility of high-definition video aerial surveys versus a traditional boat-based survey platform, an understanding of which is critical to integrating new digital survey data with historical datasets. Both survey types have methodological strengths as well as limitations. Digital aerial surveys can be conducted at a high enough altitude so that animals are not disturbed (flushed) by the aircraft. This method also has the advantage that video data can be reviewed by multiple observers. However, the degree of detection bias that exists for digital approaches has yet to be examined. Variations in detection and identification of seabirds between survey methods should be carefully considered when choosing which methodology to use for offshore surveys.

Questions & Discussion

Q: ***How much do you think higher ID rates by visual observers can be attributed to bias on the part of visual observers – i.e., being more confident in their ability to identify a bird?***

A: With any kind of visual survey, we cannot re-review something that has been identified to double-check the identification (unless you have two sets of observers). In contrast, we actually classify our video identifications into different certainty levels (our observers will say “I am less than 50% certain it is species X” or “I am >95% certain it is species X”.) There is also a blind audit process for the aerial video, in which 20% of the animals are re-reviewed. These characteristics of the aerial video review probably do make observers more cautious in making definitive identifications.

Q: ***Given the results comparing boat and aerial surveys, what would you recommend for future studies – especially as we begin to open up large ocean areas in the Atlantic and Pacific?***

A: There are pros and cons to each method. Once you start talking about very large areas that are some distance offshore, boat approaches become prohibitively expensive. Visual aerial approaches are not really feasible when you get far offshore either, both for cost and safety reasons, so for that kind of situation it makes sense to consider the digital aerial approach, as they are doing in Great Britain.

Q: ***Does the speed of boat or plane affect density estimates, and how?***

A: It should not matter. The way the estimates are calculated, it shouldn’t make any difference. But with the slower speed of the boat, there is more opportunity for animals to be moving around as the transect is being surveyed – you get less of a snapshot and more of a moving frame. (Note that the speed of the plane may affect the encounter rate for highly mobile species using this method, however—see above).

Q: ***What is the cost comparison between boat and aerial surveys?***

A: That depends on the area you are surveying. The size of the boat determines a large part of the cost; the farther offshore you’re going, the bigger the boat you need, and the longer it takes to get there (more fuel). Digital surveys are generally much more cost-competitive for large areas far offshore. Closer to shore, you may be better off with a boat.

Q: ***Might disturbance by boat have affected aerial observations?***

A: We designed this study to be able to look at that specifically. You have six replicates of each aerial transect as the boat was covering that same transect. So we have repeated aerial coverage of the same transect segments, both before and after the boat had come through – that's what allowed us to determine the disturbance effect of the boat.

Questions submitted but not addressed during session

Q: ***Without verification of the boat-based ID methods, is it possible that the aerial false ID rate is higher than the true ID rate?***

A: The "true" ID rate is unknown for either method. There may be animals that are falsely identified to the species level from the boat, as well as during aerial video review. However, the identification and audit protocols in place for the aerial data tend to have the effect of discouraging "certain" identifications, and to quickly determine when observers are making IDs with insufficient data (these approaches include requiring aerial video reviewers to estimate the level of certainty in their identifications; the mandatory blind audit of 20% of all animals; and audit resolution and ID calibration activities between video reviewers). There are no such standardized safeguards in place for the visual data collected from the boat, so it is possible that the boat's rate of identification to species may be artificially high. The use of experienced boat observers and informal "double checking" of identifications by other observers on the boat probably discourage false IDs, however.

Q: ***You made six passes with the airplane. Did you average the data from the six passes?***

A: We bootstrapped the six replicates to provide segment-level abundance estimates with associated estimates of uncertainty. 500,000 simulations were run in package 'bootstrap' in R. (Bootstrapping is a resampling approach that repeatedly takes samples from a population and recalculates a particular metric of interest – in this case, the raw count or abundance estimate. It is also a straightforward way to develop associated error or uncertainty estimates.)

Assessing Risk to Birds and Bats: Movement Across Landscape

Predicting raptor collision risk from first principles: application of updraft modeling to wind farms

Presenter: Chris Farmer, *Tetra Tech, Inc.*

[presentation]

Co-Authors: Dave Brandes (Lafayette College); Laura R. Nagy (DNV GL-Energy); Karl Kosciuch (Tetra Tech, Inc.)

PROBLEM / RESEARCH NEED

Adaptive management of the collision risk presented by wind farms to raptors, particularly eagles and other species subject to special protection, typically depends on information regarding bird movements to predict risk. The stakes are high for developers, who may be requested to re-design projects or monitoring studies, or curtail operations in response to permitting agencies' perceptions of risk. Methods of evaluating collision risk at wind farms based on observations of raptors in flight, home range analyses using telemetry data, or development of resource selection functions are all limited in their generalizability. This lack of generalized value occurs because the data inputs consist of historical information derived from the movements of a subset of individuals on the landscape over a limited time.

Objectives
This is a work in progress; the objectives are to:

- Develop a generalizable means of identifying relative risks across a landscape from first principles of fluid dynamics and biology.
- Use this improved predictive power to develop a model-based approach that can inform micro-siting and adaptive management strategies.

APPROACH

Several flight behavior studies at wind farms have shown that collision risk is highest when raptors are using orographic (terrain-generated) lift to fly at low altitude near sloping terrain. For example, detailed study of Griffon Vultures and other raptors at two wind farms in southern Spain has demonstrated that close passes near turbine blades and collision fatalities were most likely to occur when birds were soaring using weak orographic lift, near the threshold required for soaring flight. Our method uses simple inputs of terrain, wind direction and wind velocity to predict orographic updraft velocities on the landscape. Areas of risk are defined in our approach as areas where the average updraft velocity at heights corresponding to the rotor-swept zone is near the threshold to sustain an eagle in soaring flight.

Mechanics of Flight

Flight depends on a bird having lift in excess of its sink rate. Large soaring birds have to lift a lot of weight per unit of wing area, and flapping flight is approximately four times more expensive metabolically than gliding/soaring. Large soaring birds therefore depend on vertical air motion to subsidize both long-distance migration and local movements.

There are two types of lift subsidy that birds can get from atmospheric movement: thermal and orographic. Thermal lift is dynamic, and somewhat unpredictable. Orographic lift – created by the interaction of surface winds and topography – is what Golden Eagles and Griffon Vultures rely on. For Golden Eagles, the threshold updraft velocity (lift = sink) is about 0.85 meters per second (mps); for Griffon Vultures, it is about 1 mps.

When orographic lift is close to a bird's threshold updraft velocity, it leads to slow rates of climb and extended time at low altitudes. Birds moving from areas having above-threshold updraft velocities to areas of lower updraft velocity are more likely to descend. When these conditions coincide with wind turbine locations, birds are likely to spend extended time circling in the rotor swept zone and therefore be at greater risk.

Principles of Fluid Flow

Orographic lift velocity is a function of the wind-terrain incidence angle – the more perpendicular wind direction is to the direction of the terrain's slope, the stronger the orographic lift. Lift is also stronger the steeper the terrain. We can model orographic lift velocities across the landscape under various wind conditions by inputting slope, terrain aspect (to figure out wind-terrain incidence angle), wind direction, and wind speed.

We compared two applications of this model to the identification of high-risk turbine locations on differing landscapes in which the spatial pattern of raptor fatality locations is not readily discernible.

1. Case 1 - Griffon Vultures at Tarifa, Spain. Detailed study of Griffon Vultures and other raptors at the Pesur and E3 wind farms in southern Spain has demonstrated that close passes near turbine blades and collision fatalities were most likely to occur when birds were soaring using weak orographic lift, near the threshold required for soaring flight.
2. Case 2 - Golden Eagles at a wind farm in the Western United States. Rugged topography produces dramatic differences in predicted updraft velocities, but the pattern of Golden Eagle fatalities is not well predicted by observations of space use.

FINDINGS

In the case of the Pesur and E3 wind farms at Tarifa, Spain, 15% of the turbines were causing 57% of fatalities, primarily at two of the Pesur turbine strings. Slide #10 illustrates application of updraft modeling at the high risk and lower risk turbine strings. Given a 6.5 mps East wind, the model pinpoints which turbines experience "near threshold" (>90% and <110% of the Griffon Vulture's 1 mps velocity threshold) updrafts at rotor swept heights. The timing and location of Griffon Vulture fatalities was well predicted by the model (slide #11), leading to finely tuned management recommendations.

To characterize turbine risk in Case 2, we modeled updraft velocity for 13 wind conditions making up 85% of the wind regime at the project. Using a fine scale grid (30-meter grid cells) and 2 mps wind speed increments, we characterized each turbine according to the average updraft velocity within 200 m on the upwind side. Threshold updraft velocity was bracketed at 0.76 to 1.25 mps. The example on slide #14 illustrates results at five turbines: two having no fatalities, and three with one fatality each (slide #14). Under conditions of 6 mps westerly winds, the zero fatality turbines had updraft velocities either well below or well above the threshold. One of the three single-fatality turbines had an updraft velocity within the threshold bracket, but the other two were both slightly lower than the lower bracket (0.634 and 0.734 mps).

CONCLUSIONS / APPLICATIONS

Based on model validation to date, this model appears to be very worth adding to the toolbox. At Pesur, 91% of fatalities could be predicted based on the model. In the case of the Western U.S. wind farm, application of the model predicted the location of fatalities under various wind conditions, but lack of information regarding the timing of the fatalities limits our ability to apply the results to management. The model needs to be validated for Golden Eagles and other large birds at a facility that has known timing of fatalities.

As a risk minimization tool, this model has both pre- and post-construction applications.

- Pre-construction, mapping areas of threshold and near-threshold updraft velocities could augment current surveys and analyses, helping developers identify spatial patterns of eagle use in relation to the wind resource and avoid high-risk siting. It could also be used as an overlay to minimize risk through micro-siting of turbines to avoid areas of consistently low updraft velocities.
- Post-construction, the model could be used to identify turbines of greatest risk to target for fatality monitoring and adaptive management based on updraft velocities, including changes in daytime cut-in speed, informed curtailment, or targeted technology efforts.

The model can also be used to evaluating risk reduction vs. cost factors:

- Risk Factors: wind condition frequency; season; eagle use frequency; number of turbines near threshold; average updraft velocity
- Cost Factors: wind condition frequency; proportion of output at threshold conditions; scale of wind monitoring and turbine control

For detailed questions about the model, please contact: Dave Brandes, brandesd@lafayette.edu.

Questions & Discussion

Q: *How did you calculate the threshold updraft velocities for species?*

A: It is a function of wing area and some dynamics equations that were first published by Pennycuick (Flight 1.22 model, Pennycuick 2008). The threshold velocity is determined using the glide polar – a graph of sink rate vs air speed. The minimum sink rate of the bird is equivalent to the minimum vertical updraft speed to keep the bird aloft. You need to know a few things about the species: average size information for the wings, average weight. The glide polar can then be constructed using the Flight 1.22 model, available at http://www.bristol.ac.uk/biology/people/colin-j-pennycuick/index.html
Reference: Pennycuick, C.J. 2008. Modeling the flying bird. Elsevier (Academic Press). ISBN 978-0-12-374299-5.

Q: *In the model, did higher wind speeds factor into the resulting risk rank?*

A: Yes, for any given wind direction scenario, when wind speeds are lower, more turbines are at orographic lift thresholds or below; at higher speeds (over 8 m/s), few of them are at or below threshold.

Q: ***Did the size of the area of updraft correspond to fatalities or risk measurement in model output?***

A: We were not able to assess that. We were working with resolution of the DEM which allows us to model 30m x 30m cells. One thing we had to assume was the distance at which the bird is actually entering a zone of risk. We set this at roughly 200 m, or two rotor diameters out. We can change the size of the area we average over, but we cannot change size of analysis grid cells.

Q: *Was there a threshold for minimum acres of upslope for inclusion in the model?*

A: No. We get the terrain model, pick our wind scenario and model the movement of air as a fluid across that surface. Anything that is a grid cell size or higher will show whatever deflection is caused by the terrain. However, larger sloping areas will generate larger areas of vertical air movement.

Q: *Why are we not seeing Golden Eagle mortality at Appalachian ridgeline wind farms?*

A: One reason is that there is a lot of orographic lift ~~is~~ being generated along the Appalachian ridgelines. Those updraft velocities are quite strong – so the eagles are moving quickly, relatively close to the ground (within the rotor-swept area). Because they are moving quickly along a migratory path, trying to cover ground, they are probably looking ahead, not focused on the ground. They're also not spending time circling. So, although there are a lot of turbines along those ridgelines, the eagles are not engaging in the most risky behaviors.

Q: ***Does this model apply equally to migrating Golden Eagles and resident Golden Eagles on territory?***

A: Probably not so much. During migration, we see less risky behavior. It's the circling in close proximity to turbines and close proximity to the ground that puts the eagles at greatest risk. In the migration corridors you are more likely to see birds using the air space in way that doesn't put them at such great risk.

<u>Questions submitted but not addressed during session</u>

Q: ***Downslope winds were not discussed. Please comment.***

A: The primary orographic updrafts of interest are produced by the deflection of winds by the component of the topography that is on the upwind side of topographic features. The model does not simulate airflow in the down-sloping areas. Airflow on the downstream side of an obstacle (mountain, hill, tree, rock) is highly turbulent and difficult to predict due to vortex shedding etc. However there can be some uplift low on the downstream side of a ridge due to the formation of vertically oriented eddies where air circulates down over the valley and up close to the downside side of the ridge. The model is too simple to simulate this phenomenon. Computation fluid dynamics models based on Navier-Stokes equations are needed for that, and we believe that updraft velocities near the turbines are most important in predicting risk.

Patterns in diurnal airspace use by migratory land birds along an ecological barrier

Presenter: Anna Peterson, Western State Colorado University

[presentation]

Co-Authors: Gerald J. Niemi (University of Minnesota, Duluth); Douglas H. Johnson (U.S. Geological Survey)

<u>PROBLEM / RESEARCH NEED</u>

During autumn migration, the northern coastline of Lake Superior acts as an ecological barrier for billions of southeast migrating land birds that breed across the boreal forests of Canada and Alaska. An "ecological barrier" is any feature that changes animal behavior.

To the extent that this same coastline, along with other Great Lakes coastline, are viewed as significant wind energy resources, we need to measure and be able to predict how species are using this airspace.

Objectives

The objective of this research was to explore the spatial and temporal patterns that characterize the aerial distribution of diurnal migratory land birds along the northern coastline of Lake Superior.

APPROACH

From 24 observation points, we assessed the diurnal movements of birds throughout autumn migration, August through October, within a 10 km by 210 km coastal region along the north shore of Lake Superior. A total of 13,702 raptors were recorded over the three-year period (2008-2010) and 151,550 non-raptors (of which 90% were passerines) were recorded during 2009-2010.

Data were recorded on topographic maps and then entered in GIS. Airspace was defined in four dimensions: latitude, longitude, altitude, and time of day. Flight height was classified in three categories: from tree canopy to 100 m; 100-500 m; and 500+ m. We looked at a variety of spatial and topographic features, including distance from shore, presence of a major ridgeline parallels the shoreline, and distance from Duluth, which is located at the southwest tip of Lake Superior, hence at one tip of the eco-barrier.

FINDINGS

Several raptor species showed patterns in airspace associated with topographic features such as proximity to the shore and presence of ridgelines. Funneling movement, commonly used to describe the concentration of raptors along a migratory diversion line that either prevents or enhances migratory movement, occurred only for Bald and Golden Eagles. This suggests a "leaky" migration funnel for most migratory raptors, and that we are likely underestimating number of raptors upstream of the funnel.

We saw different temporal patterns of airspace use; buteos were more commonly observed in the afternoon, while falcon observations were fairly evenly distributed throughout the day. Most passerines were observed during the first two hours after sunrise. Passerines migrating during the late-season showed more spatial and temporal structure in airspace distribution than raptors, including a stronger funneling pattern and an association with airspace near shore.

With regard to flight height, most birds are moving within 100 m of the tree canopy. In the case of species of concern (e.g., the Rusty Blackbird, a bird of continental concern), we can use this flight height information along with season, time of day, and their funneling along north shore of Lake Superior to build species-specific patterns of airspace use (slides #15-17).

CONCLUSIONS / APPLICATIONS

We conclude the following.

- The diurnal use of airspace by migratory land birds is patterned in space and time;

- Autumn count sites substantially underestimate the number of raptors due to ‘leakage’ out of concentration areas
- The magnitude and structure of diurnal passerine movements has been overlooked.
- The airspace associated with anthropogenic development (e.g., buildings, towers, turbines) is heavily utilized by migratory land birds and necessitates management and conservation attention.

This study looked only at diurnal migrants. We will have to look at nocturnal migrants as well, including bats. Radar images from one hour around sunrise show birds moving along the shoreline as well as over the water. A future direction for this research would be to look at patterns of airspace use over the lake.

[This work will be published in 2015: Peterson et al. In Press. Ecological Applications]

Questions & Discussion

Q: ***How accurate do you think your flight height estimates are, and how biased are they towards lower altitudes given that birds are easier to see when closer to observers?***

A: We used topographic maps as datasheets. A lot of times our observation sites were at an elevation above where birds are moving – over 100 feet above the surrounding landscape. We put that data into categories, but for the low-moving birds, so we are actually quite confident because in many cases they were flying below the height of the observer. We put data in categories because we were not sure how to exactly estimate. We are quite confident about low-flying birds, but less certain about high-altitude birds.

Q: ***Was weather pattern at the time of migration considered in the “funneling” analysis? Current high/low pressure systems and frontal zones could influence temporal and spatial trends in movement.***

A: The quick answer is no, but note that most of the weather systems are coming from Northwest. Way we analyzed our results was to take means. When those birds are within that corridor, what are the spatial patterns? And when they were in that corridor, most of the winds are from the Northwest. When winds were out of the east, we didn’t see birds in the corridor, so in general, no – we didn’t take into account weather patterns.

Q: ***Have any bats been detected offshore from the Pacific coast?***

A: Not yet. I don’t know of anyone monitoring that.

Q: ***Do you anticipate generating a spatial model for industry to use from your research?***

A: That was the idea going into this. The study itself was not wind-turbine based, but we would like to see these spatial models developed all along the Great Lakes shoreline – there are a lot of people, including us, who would love to see that happen.

Q: ***In general, what is the influence of wind speed on funneling, and how do strong westerly winds influence funneling in your North Shore study area?***

A: We did incorporate wind speed and wind direction into the models. When wind is from east, we don't see funneling, because birds are essentially being blown out of corridor. Wind speeds did not seem to matter for most species, maybe because we saw so many westerly wind days. Especially for eagles, wind speed and even direction did not matter. For a couple of other species, wind direction did influence patterns.

Bat Acoustic Monitoring Portal (BatAMP): an online tool for visualizing continental movement patterns of bats and informing wind energy siting decisions

Presenter: Theodore Weller, U.S. Department of Agriculture Forest Service

PROBLEM / RESEARCH NEED

Large-scale planning efforts for renewable energy projects are hampered by a lack of data on the occurrence of bats at large spatial scales. Fatalities of bats at wind energy facilities are primarily concentrated during migratory periods, but the timing of migration and, especially, the migratory pathways of bats are poorly known.

The hoary bat, for example, is widely distributed across North America, but appears in different parts of its range at different times of year. We know that these bats roost solitarily in trees and that they migrate, but we have few specifics. Stable isotope analysis tells us that some of these bats seem to be moving north-south and some east-west. Hoary bats are hard to encounter or capture, and consequently there are very few records, and very little data.

There do exist a considerable amount of data about bat locations from wind energy facilities that have used (or are now using) pre-construction echolocation detectors. Hoary bats are easy to identify from acoustic data, but there hasn't been a way to compile these data. A central clearinghouse for echolocation records could help elucidate seasonal patterns of species presence at the largest spatial scales.

Objectives

The first objective of this project was to develop a relatively easy way of compiling acoustic data on hoary bats from pre-construction echolocation detection surveys. The goal is to use these data to learn about the basic ecology of bats and gain insights into landscape level siting decisions.

APPROACH

We developed an online data portal – BatAMP – that compiles datasets and allows visualization of the results of echolocation monitoring efforts. The portal accepts data from all types of bat detectors and species identification processes in a simple night-by-species matrix. Echolocation records can be uploaded into the database from a spreadsheet or comma-separated value (CSV) file.

The portal includes visualization applications as well as interactive and customizable features. An example (using data shared from McNary National Wildlife Refuge) demonstrates how BatAMP enables us to look more closely and see what is happening over time and in detail at a given site. (Slide displays mapping feature that shows where and when bats appear.) With additional data sets, we could begin to put a meaningful picture together of when and where hoary bats are across a large spatial-scale landscape. (We were surprised, for example, to see high levels of bat activity at locations in Alaska.)

In addition to uploading the acoustic dataset, users complete a meta-data form that collects basic information about the source of the echolocation records. To make participation open to as many collectors as possible, there are opt-outs for privacy; participants can choose whether to allow datasets to be downloaded or not. Older datasets can be uploaded as well as current ones.

FINDINGS

By compiling and providing interactive access to data from echolocation monitoring efforts at wind energy facilities and elsewhere, BatAMP gives wind energy developers, biologists, and agency personnel tools to:

- Compare activity rates of bats at proposed wind energy facilities to other habitats
- Understand the timing and geographic distribution of bat migration
- Incorporate bat distribution data in landscape level planning tools.

BatAMP helps us to understand bat activity at or near a prospective wind energy site in the context of a larger region, and to compare activity at a prospective or active wind energy site not only with other wind energy sites but also at non-wind energy locations in the region. Looking at bat activity across California during the month of March, for example, we found hoary bat activity within the Tehachapi wind resource area, but much higher levels of activity in metropolitan Los Angeles. (The locus of this activity turned out to be the L.A. Zoo.) This illustrates that simply comparing one wind facility with others may not provide a complete picture of the relative levels of bat activity and hence a holistic assessment of relative of siting risks to bats.

CONCLUSIONS / APPLICATIONS

The same data portal can be used to help advance other conservation efforts for bats, such as consolidating information on winter activity to better understand the timing and geographic distribution of bats affected by White-nose Syndrome. Ultimately the BatAMP provides a platform to leverage our collective data to address a broad suite of conservation concerns for bats and reduce risks to their populations due to wind energy development.

We encourage regulators and others to use this tool to share data.

Questions & Discussion

Q: ***What format does data need to be submitted in?***

A: It just needs to be in an Excel spreadsheet or a text file as demonstrated in my presentation. The meta data is entered separately into an online form.

Q: ***Any bats detected off the Pacific coast?***

A: Not that are represented in the data portal as yet. We know that hoary bats are at least infrequently active over the Pacific during autumn migration, because they are found annually in low numbers on the Farallon Islands near the San Francisco Bay Area. I'm not aware of anyone who is currently using acoustic monitoring off the Pacific Coast.

Q: ***Any connection between BatAMP and the North American Bat Monitoring Program?***

A: There is no connection, but we have coordinated extensively. BatAMP is optimized for long-term collection of echolocation monitoring at a single site, whereas NA Bat focuses on driving transects from a single night (or surveys conducted over a few days). They are not equipped at the moment to deal with longer-term echolocation monitoring data, so they have encouraged us to go ahead with what we're doing, with the idea that we will link up later.

Q: ***Can you speak about the limitation of bat detectors' ability to estimate abundance at a given location – i.e., numerous call sequences could be made by numerous individuals or by one bat making multiple passes. Will BatAMP consider this, and if so, how? Will it actually be able to identify migration corridors?***

A: One cannot necessarily tell ten bats passing the microphone from one bat passing ten times. It is better to refer to it as "bat activity" rather than "bat abundance." However, particularly at low numbers, I believe acoustic call records to be a decent index of abundance. Some of the patterns I showed are strongly suggestive of migratory corridors but we need more datasets to say this with any confidence. I view BatAMP as a way for to identify patterns in the data or potential patterns that require focused research to address. I speculate that it will be relatively easy to identify areas of high or low bat activity and that these could be useful in broad-scale siting decisions for wind energy.

Q: ***Is there a quality assurance method for data uploaded into BatAMP?***

A: There are numerous fields in the meta-data sheet where contributors can describe how data were analyzed – for example, 'Did you rely on a call identification program?' 'Did you do any validation work?' We do not plan to evaluate species IDs or do any QA on species identifications at the moment. This is too time consuming and variability can arise at many stages in this type of work. That said, these types of datasets processed by a variety of methods and experience levels are the basis of environmental assessments of wind farms and publications on ecology of bats. When we look at many datasets and broad-scale patterns my sense is that the true patterns will emerge. Outliers will also be apparent.

Questions submitted but not addressed during session

Q: *What about an effort like eBird?*

A: eBird is the model upon which this idea was based. I encourage anyone interested to check out eBird on-line to get a feel for the power of combined data! It is amazing. We will never get to the level of resolution that eBird achieves, but I believe it is worthwhile to move in that direction. Note too that most of the data that forms patterns in eBird is not QA'd at the survey-level. My understanding is that only very rare observations receive any QA and these are conducted by a regional volunteer.

Q: *How expensive is it to purchase a unit and connect to BatAMP?*

A: A system capable of monitoring autonomously for long periods of time using solar power can be assembled for $1-2000 depending on quality etc. Be forewarned that these units operate every night and record large volumes of data that must be processed. Species ID is somewhat automated but takes time and some expertise to do so. Multiple workshops are offered annually to get experience with these methods. Participation in BatAMP is free to anyone who has a fully processed dataset and would like to submit. Just contact me to get started with BatAMP.

Estimating Impacts to Birds and Bats: Understanding Impact Mechanisms

Quantified reactions at a distance of birds and bats to wind turbines

Presenter: Ronald P. Larkin, Illinois Natural History Survey, University of Illinois

PROBLEM / RESEARCH NEED

More bats than birds are killed at night during the migratory season, which means that the bats are much more vulnerable than birds to wildlife/turbine interactions. To understand why bats are vulnerable and to shed light on the mechanism of bats' encounters with turbines, we need to observe their behavior not only within the zone of risk, but as they approach it from a distance.

It is assumed that flying animals either are or aren't attracted to turbines, and once in the vicinity of a wind turbine or array of turbines, either avoid or do not avoid these structures. Radar cannot observe birds or bats right at the turbine, but it can be used to assess the flight height and distance at which they react to turbines, and whether their response is one of attraction or avoidance.

Objectives

The objective of this project was to gather multi-dimensional radar data on the flight paths of both birds and bats flying near operating commercial-scale turbines. These data will inform estimates of risk by providing information on the number of animals exposed.

APPROACH

We gathered data using a unique, specialized radar that could track single animals from a distance of over 2 km, and discriminate bats from birds and arthropods by wingbeat records. Two of the field sites were in Illinois and one in Southwest Pennsylvania; we additionally looked at four sites in Texas.

To provide unbiased evidence and generate estimates such as the distance at which animals react to turbines, a completely automated assessment was conducted using an algorithm to examine the four-dimensional tracks (x, y, z, time). The algorithm provided input to computerized estimators of reactions in horizontal flight and height for animals flying in the vicinity of turbines and meeting quantitative criteria. To check algorithm performance, a skilled observer manually classified the same tracks using interactive plots.

FINDINGS

A total of 1,829 flying animals were picked up by the radar, including bats and birds whose flight paths were quantitatively and also manually classified as “attracted”, “avoided”, “no reaction”, or “not classifiable.”

Presentation includes examples of birds and bats picked up by the radar. In the first, a migrating bird appears to be “flap-coasting” in the vicinity of turbines at Casselman, PA. The radar track shows the bird – which is flying at height of turbine rotor – first approaching and then avoiding the turbine. The “tail” section of the track determines whether the bird either is attracted to or avoids the turbine. (Note that “avoid” or “attract” are objective determinations based on the computer’s algorithm.) In the second, a bird appears to veer away, but because it was already flying well above the rotor swept area, it is not clear whether this constitutes avoidance.

Radar imagery shows that, whereas birds tend to turn away from the turbines, bats more consistently turn towards them. The presentation includes one example of a bat flying well above the rotor swept area that clearly changes its path to go directly over turbine string. Other tracks captured by the radar show some bats being attracted in the vertical direction (generally down) as well as in the horizontal dimension.

Unexpected spontaneous turns, climbs, and descents on the part of the bats complicated the analysis, behavior that often took bats far above turbine height. Nevertheless, automated and manual assessments of avoidance and attraction agreed ($p < 6 \times 10^{-4}$). Completed analysis shows that some bats as far as 700 m away were observed to be attracted to turbines, explaining bats’ high mortality. The result is in agreement with thermal imaging observations near blades of turbines and with hypotheses of bats’ trophic and/or reproductive behavior around turbines.

CONCLUSIONS / APPLICATIONS

Contrary to conservationists’ suggestions, making turbines easier for bats to detect could increase rather than decrease fatalities. Birds flying toward or near turbines at the same sites during the same observations either flew straight past them or explicitly avoided them by turning away or ascending above rotor-swept height. These radar data on birds show that models of bird mortality at turbines that assume random “tennis ball thrown at a fan” encounters with turbine blades are not useful and overestimate risk to birds.

Environmental covariates of avian turbine mortality

Presenter: Julie Beston, U.S. Geological Survey (USGS)

Co-Authors: James E. Diffendorfer, Wayne E. Thogmartin, Richard Erickson, Jessica Stanton (USGS)

PROBLEM / RESEARCH NEED

Wildlife mortality from collisions with turbines is one of the most obvious impacts of wind energy generation. Both the characteristics of the turbine itself and the environment in which it is placed are likely to contribute to the amount of mortality it causes. By identifying the factors correlated with annual fatalities at individual turbines, we hope to be able to minimize fatalities.

Objectives

The objective of this project was to investigate the covariation of estimated mortality rates with turbine characteristics, land cover and topography.

APPROACH

We looked at publicly-available studies with turbine-specific mortality data from 30 wind farms to estimate mortality rates. The studies were spread out across the U.S., but are not necessarily representative of where turbines are located. A total of 1,226 turbines were included in the analysis.

We then developed a hierarchical model in which the number of observed mortalities (y) was binomially distributed with parameters equal to the total number of actual mortalities (n) and the observation rate (p). The number of actual fatalities was assumed to follow a Poisson distribution with mean a function of turbine characteristics, environmental covariates, and study duration (t) and timing (e.g., summer only, year-round) to estimate total expected annual fatalities. (For this talk, the observation rate (p) was taken directly from the studies.)

Turbine characteristics considered were the MW capacity of the turbine, hub height and rotor-swept area. Environmental covariates included land cover within 100 m, 1 km, and 10 km; topography; and latitude and longitude.

We constructed a suite of models and used deviance information criterion (DIC) for model selection. Top models all included landcover variables at the 10 km scale. Variables that had correlations greater than 0.5 or less than -0.5 were excluded to remove co-linearity. The top model had six parameters including the intercept.

FINDINGS

Looking at all 1,226 turbines using the top model, avian fatalities average 3.57 birds/turbine/year; there is a narrow confidence interval on that mean, but a fairly wide range – from fewer than 1 bird/year to over 28 birds per year. We set other factors to their mean values to look at the unique effect of each factor of interest. By breaking out the expected variation in fatality numbers at each of these turbines, we could see how much of that variation is due to differences in these factors that we modeled:

- Deciduous forest cover is the major driver (44%) – turbines in these lands kill a lot more birds than do turbines in non-forest cover

- Hub height is also important (26%), as other studies have also found
- Barren land values were small, but because it is highly correlated with developed land and pasture and hayland, the combined value is significant (24%)
- Higher latitudes and wetlands cover also contribute (3% each), but not much

CONCLUSIONS / APPLICATIONS

Our preliminary conclusions are that taller turbines kill more birds. We also found that the 10-km landcover models have better predictive value than than 100-m or 1-km models – which suggests that facility-siting is more critical than siting individual turbines.

It is difficult to say exactly which landcover types are driving these relationships because a lot of them are correlated. (For example, grassland and cropland are negatively correlated with some of our included factors.)

Other factors we would like to add include:

- Turbine lighting – lack of correspondence between study reports and FAA data as to which towers are lighted poses an obstacle.
- Topographic convergence index – e.g., is turbine on a plain, ridgetop
- Density of turbines
- Location of turbine in facility – suggestions welcome as to how best to categorize, given many different possible configurations.
- Bird abundance – is landcover correlated with bird abundance? Or are there some types of locations that are more attractive to birds?

Other future directions for this research are to look at species-specific fatality correlates; we will probably start by looking at Horned Larks, because there are a lot of documented Horned Lark fatalities in our dataset. We also want to look at facility correlates, given that the 10 km buffer proved to be the best scale for looking at landcover variables.

Questions & Discussion

Q: ***Did you stratify the analysis based on proportion of the land cover types available within 10 km of the facilities included in the study?***

A: No.

Q: ***Your model included a term for length of surveyed period. Does that assume that fatalities occur at the same rate throughout year?***

A: No – we looked at full-year studies and split out their fatalities by month to calculate what would be occurring during the study period.

Q: ***Could you please elaborate on how you dealt with high levels of correlation between habitat variables in your model, and also whether the 100 m, 1km, and 10km-scale habitat data were correlated with each other?***

A: We actually did a principal components analysis of the landcover at each of those scales. At the 100 m scale, landcover types were not correlated with each other – nor in most cases were they correlated at the 1 km scale (except for deciduous and mixed forest cover). We saw the most correlations among the landcover types at the 10 km scale. I did do a PCA, and used the first three components. The loadings were very even among the components, and several landcover types loaded onto multiple components, and it became difficult to tease apart which of those landcover types were actually driving the relationships between the principal components and the fatalities. So I ran all of my single-variable models for each landcover type by itself as well as the turbine specs and those topography specs, and then I built my models up using the model with the best DIC value of a set of correlated models. So, for instance, the deciduous and mixed forest were correlated with one another, the deciduous on its own had a smaller DIC value so I built up from there. Some assumptions and limitations.

For some landcover types there were correlations among the buffer sizes, for other types there were not. Crop cover had the strongest correlation among the different buffer sizes; most of the landcover types were not highly correlated at those different buffer sizes.

Q: ***Of the average 3.6 bird fatalities per turbine per year, about what percent are local breeding birds vs. migrating birds vs. wintering birds?***

A: I do not know.

Q: ***Are taller turbines killing more birds even if you calculate birds per rotor-swept area? That is, is it a matter of height alone, or of a larger RSA?***

A: There was an approximately 83% overlap of those two factors (turbine height and RSA) in my data set, so it wasn't possible to tease those factors apart. Height just happened to correlate best with fatalities.

Displacement of breeding grassland birds by upland wind facilities

Presenter: Jill A. Shaffer, U.S. Geological Survey

Co-Author: Deborah A. Buhl, U.S. Geological Survey

The U.S. Geological Survey, Northern Prairie Wildlife Research Center conducted a long-term (>10 year), Before-After, Control-Impact (BACI) study that evaluated the displacement effects of three wind facilities in North Dakota and South Dakota on grassland birds in native grasslands.

We assessed the immediate and delayed effects of wind facilities for nine bird species and presented results for three of those species.

To test for an immediate effect, we computed the change in density from the pre-treatment year to one-year post-treatment, and then compared this change in density between turbine and reference sites. To test for a delayed effect, we computed the change in density from the pre-treatment year to the two- to five-year post-treatment average. The BACI design allowed us to examine this question in two ways: 1) to test the prediction that overall densities of individual species on wind facilities will change from pre-construction to post-construction, relative to reference sites, as a result of disturbance or attraction, and 2) to assess the effects within 100-, 200-, 300-, and >300 m from turbines.

Displacement varied by species, study area, and time period. We found evidence of displacement at all three wind facilities for one species, evidence of displacement for six additional species at at least one wind facility, and no evidence of displacement for two species, one of which exhibited attraction. Some species exhibited only immediate or delayed effects, whereas others exhibited immediate and delayed effects. Some species exhibited within-site displacement (i.e., they re-located from the area nearest turbines to areas farther from turbines, but still within the study site), whereas others exhibited overall displacement (they moved off the study site).

Questions & Discussion

Q: ***Grasshopper sparrows can be sensitive to vegetative structure. Was this constant during the study period?***

A: All of the study sites, both treatment and reference sites, were actively grazed every year of the study. Therefore, vegetation structure was relatively constant throughout the duration of the study. Any yearly variation that might have occurred would have been accounted for through our analytic methods of comparing change in bird density between treatment and reference sites. We also compared vegetation structure among treatment and reference sites and found no significant differences.

Q: ***You show absolute changes in density for these species. Did you look at relative changes? If so, how large were relative changes in density?***

A: We did not look at relative change.

Q: ***You said you had only one year notice – how can scientists and industry work together to get earlier notice so that we can expand pre-construction studies?***

A: The ability to obtain 2-3 years of pre-construction data on treatment sites would strengthen the study design and conclusions. Industry would need to be able to share the locations of individual wind turbines that far in advance. Good communication and relationships between industry and researchers would be necessary to ameliorate any industry concerns over releasing that information.

Q: ***Could gravel compaction and maintenance grading possibly be the cause of no long-term attraction for killdeer?***

A: Any activity that causes nest failure could be responsible for Killdeer not returning beyond the first year post-construction, whether nest failure is due to vehicular travel or predators. Gravel compaction probably would not deter Killdeer from forming a nest scrape, but increased vehicular disturbance due to activities such as maintenance grading could cause nest failure. Predators could be using turbine roads as travel lanes and thus come in more frequent contact with Killdeer and their nests. Predators may learn that roads harbor Killdeer nests and learn to search for nests, thus reducing nest success. If Killdeer realize turbine roads are low-quality nesting habitat, their decision to nest elsewhere might manifest itself beyond the first year post-construction as a lack of attraction for areas near wind turbines.

Q: ***Did the post-treatment include a construction phase, and if so, did you see a difference between the construction and operation phases?***

A: Post-treatment did not include the construction phase.

<u>Question submitted but not addressed during the session:</u>

Q: ***You said that the South Dakota Wind Energy Center may have exceeded a disturbance threshold. How can we use this data in cumulative impact analyses prior to siting?***

Based on our study, it is possible that Western Meadowlarks exhibited a disturbance threshold at the South Dakota wind facility. However, our study was not designed to directly answer such a question. At this point, it is simply a hypothesis. Further, multiple studies specifically designed to address this question would be necessary.

Conservation status of North American birds in the face of future climate change

Chad Wilsey, Audubon Society

[presentation]

Audubon is happy to share some of our research today. Our goal is to demonstrate how some of the climate change products we are producing can have benefits for siting.

Specifically, I will give an overview of a report that Audubon released in September 2014– forecasting potential impacts on birds from climate change. Several years ago, Audubon scientists dreamed about creating an Audubon Guide to Future Bird Ranges. It would be similar to guides we use today with maps of summer and winter distributions, but for the future. Once we had that guide, we could look across species and identify which are likely to fair well under climate change, and which may struggle. Even better, we could use those maps to prioritize places across the landscape that are more resilient to climate change, and therefore likely to remain suitable for birds today and into the future.

Audubon's Conservation Science Team has created three science products – Climatic Suitability Maps, Climate Sensitivity Lists (which species most sensitive to climate change), and Climate Prioritizations (areas to target for conservation) – that we hope will be useful in guiding bird conservation.

Climatic Suitability Maps
We used the Christmas Bird Count (CBC) dataset to characterize winter bird distributions, and the USGS North American Breeding Bird Survey to characterize summer bird distributions. Both have very good coverage in the U.S. and southern Canada. We related those observations to 17 bioclimatic variables to identify birds' climatic suitability. Variables included precipitation, temperature, and seasonality. We took observations of where birds were present and absent and related that to historical climate to build bioclimatic distribution models for 588 species of North American birds in total, including summer distribution models for 475 species, and winter distribution models for 503 species.

Using multiple General Circulation Models, we ran three future greenhouse gas emissions scenarios (low, medium, high) to get projections of future climate for the decades 2020, 2050, and 2080. We input those future climates into our bioclimatic models to get maps of future climatic suitability for each of the 588 species. An example of an animated map can be found at climate.audubon.org. The map shows the approximate current winter and summer range of a species, and shows the shift over time. The darker the intensity, the more probable the species will find suitable climate. For example:

- Under the high emissions scenario, climatic suitability for the Eastern Bluebird changes shows a marked movement north.
- For the Bobolink, we see a similar shift to the northern boreal zone.
- For the Sage Grouse, we see a shrinking of the climatically suitable zone.
- Burrowing Owl shows a shifting but also a shrinking of climatically suitable habitat.

Climate Sensitivity Lists

We then categorized each species as climate stable, threatened, or endangered. "Climate stable" species are those expected to lose less than 50% of their current climatically suitable habitat, while potentially seeing a net expansion of range resulting from climate change. Species whose habitat is expected to shift by 50% or more we consider "climate threatened", because even if the range remains the same size, it is not clear how well the species will be able to track the shifting habitat/range. Species whose range is expected to contract by more than 50% of their current range with no net gain are categorized as "climate endangered." We found:

- 274 Climate Stable species
- 188 Climate Threatened species
- 126 Climate Endangered species

We compared these designations with more traditional designations of conservation status: For the 314 climate threatened or endangered species, there is a very small sliver that are currently considered threatened under existing classification systems – that is, apart from any threat represented by future climate change. Climate change represents a new and important threat for most of these species.

Climate Prioritizations

The purpose of the climate conservation maps is to help us think about how best we can be focusing our efforts for species and suites of species. How do we translate these scientific models into on-the-ground conservation efforts?

One challenge is that our projections are based on several possible scenarios, leaving several sources of uncertainty: How much emissions? How will climate system respond? How will birds respond to the changes? We had to take these uncertainties into consideration in modeling spatial prioritization. Spatial prioritizations are not species distributions, but rather a way to rank the conservation value of climates across a landscape for one or more species. Spatial prioritizations incorporate multiple:

- Climate scenarios
- Future time periods
- Hypotheses about how birds might respond to climate change

In thinking about the last point, we can think about species' ability to biologically respond as a function of its mobility and its capacity for tolerating/adapting to climate change. Species that are unable to colonize new areas and intolerant of new climates will likely suffer in place. Similarly inflexible species that can colonize new areas will likely track and move with their climatically suitable range. There may be some species that are highly adaptable to new climates and simply stay where they are, adapting in place. Finally, there may be mobile species that tolerate a range of climates that are unpredictable but unlikely to be negatively impacted by climate change.

The range of possible responses suggest three approaches to spatial prioritization: prioritize future habitat for mobile species; prioritize what remains of current range for species that have to "suffer in place"; prioritize current range for species that can adapt in place. We then take the best of each of these three approaches to generate a final "hedge-your-bets" prioritization that reflects all of these potential biological responses along with the uncertainty associated with emissions scenarios and time periods in the future. This final product synthesizes all of this information into one map.

Slide #22 shows an example of a spatial prioritization map for Wood Thrush in the summer. The prioritization ranks 10-km grid cells between zero and 1 with 1 representing the highest priority. High priority areas (darker green) have consistently high current and future climatic suitability across time and emissions scenarios. Low ranking areas have low current and future climatic suitability. Areas ranked as zero are climatically unsuitable in the present and future. The black outline is called the kappa range and it reflects the modeled core climatic suitability in the present.

Audubon is focusing on what we refer to as "climate strongholds" for purposes of conservation planning and development siting. We define a stronghold as an area that is relatively valuable for retaining one or more bird species while accounting for the potential effects of future climates on their distribution. Examples would include:

- The top 10% of ranked grid cells within a state or flyway
- The top ranking existing protected areas or important bird areas within a state or flyway

Slides #24-27 show examples of spatial prioritization maps for three individual species and for a suite of species (in this case, 37 species of grassland birds). These maps include an overlay showing wind development, but could similarly be used for other types of proposed development. Audubon encourages stakeholders to make use of these interactive maps and to contact us with any comments or questions at climatescience@audubon.org.

QUESTIONS & DISCUSSION

Q: ***In your analysis of species at risk of climate risk, is there overlap between climate risk and renewable energy development risk?***

A: We did not specifically look at energy development-related risk, but we did look at whether the birds are currently endangered or threatened. For example, Sage Grouse are climate endangered species. Greater and Lesser Prairie Chickens are climate threatened or endangered.

Q: ***In your modeling, did you consider how habitat might change as well as climatic suitability?***

A: We expect that rates of change for climate variables and habitat variables will be somewhat out of sync. Habitat change occurs at a potentially a slower rate than climate change. Prioritizations do not assume that species will move at the same rate as climate change. Our objective is to identify specific areas on the ground that we want to prioritize for future habitat. Incorporating vegetation and habitat variables into the model is something we want to develop in the future.

Q: ***The American Meteorological Society publishes an annual summary of what we know about climate change. It suggests that regional models change rapidly, and that it would be better to use landscape models on a larger scale. Yet your mapping of changing climate suitability is on a very fine scale (10 km grid); how are you deriving that?***

A: We used statistically downscaled models from global circulation models. We have not used any output from regional models. Our outputs are summarized at 10 km resolution, which is pretty fine scale but not highly detailed. Clearly, when looking at specific conservation priorities or potential development sites, our maps would need to be combined with higher resolution landcover maps.

Estimating Impacts to Birds and Bats: Monitoring, Estimating, and Mitigating Fatality

Designing fatality monitoring to detect a rare event

Presenter: Manuela Huso, *U.S. Geological Survey*

Co-Authors: Daniel Dalthorp (U.S. Geological Survey)

PROBLEM / RESEARCH NEED

The current site-monitoring protocol and statistical tools we have for estimating actual fatality from observed carcasses are fairly robust when the numbers of observed carcasses are relatively high, but a non-zero estimate of the dead population using Horvitz-Thompson based estimators can only be achieved if at least one carcass is found. When the target population is small, as might be expected for endangered species, the likelihood of finding no carcasses of the target population may be high, yet observing no carcasses cannot necessarily be interpreted to mean no or even low numbers of dead individuals. When we expect to find a small number of carcasses or even no carcasses, we need a new protocol and estimators that can give us precise estimates and provide evidence as to whether a set limit has not been exceeded.

Objectives

This presentation describes an alternative statistical approach to addressing this problem.

APPROACH

Given that there may be anywhere from 0-50 Indiana bat fatalities on the wind farm, we need to know whether the actual number is closer to zero or to 50 – even if we find none. To begin with, we need to know something about the probability of detection. If the probability of detecting a carcass is large, and we find no carcasses, it is likely that there are no or few carcasses to be found – if there were many we would have found some. However, if the probability of detecting a carcass is small, we cannot draw an "evidence of absence" conclusion from the absence of evidence.

Consider this "stump the statistician" analogy: someone rolls a die five times, then reports to a friend that he rolled no sixes and asks: "how many times did I roll the die?" The friend divides the number of sixes observed (zero) by the probability of rolling a six on any given roll (1/6 = 0.167), and concludes that the die has been rolled zero times. Of course, this is incorrect in this particular case, but it is the best guess that a Horvitz-Thompson type estimator can provide. This is analogous to a situation in which there are five dead bats on the ground, but the probability of detection is only 1/6. Even if we know precisely the probability of detection, the best we can do is to bracket the range of possible fatalities (in this case, somewhere between zero and 17 because there is <5% chance of rolling no 6's if one rolls >17 times). We can narrow the bracket by increasing the probability of detection; as the probability of detection approaches 1, the closer our estimate of fatalities will be to the actual number.

We can use an approach based on Bayes theorem to help us estimate what might be out there even when we find none. In a Bayesian world, we have to have a prior. What do we know about the number of fatalities that might be out there? Let us start with an uninformative prior – we know nothing. Then, if we can estimate the proportion of bat carcasses falling in the searched area (0.5), the probability of a carcass persisting unscavenged until the area is searched (0.7), and the probability of a searcher finding it (0.4), we come up with an overall probability of observing about 14% of the fatalities. As with the die-rolling analogy, if we do not find any bat carcasses during a search, the number of actual fatalities is *most likely* zero, but it is entirely possible that there are more. In fact, one cannot rule out (with 95% credibility) that there may be as many as 19 fatalities.

We can narrow this bracket by increasing the probability of detection: that is, by increasing the number of turbines searched, decreasing the search interval, decreasing the credibility threshold from 95% to 90%. If by changing our protocol in these ways we are able to increase the overall probability of detection from 14% to 40%, then a finding of zero carcasses gives us a more useful range of possibilities: that the actual number of fatalities is not likely to be more than four. To narrow the range even further – actual Indiana bat fatalities ≤ 1 with 90% credibility – the absence of evidence (zero carcasses found) would have to be paired with a 70% probability of detection.

FINDINGS

To review, the process begins with whatever take limit has been set. We then need to agree on a reasonable level of credibility, and determine the probability of detection necessary to achieve that goal. The next step is to design a search protocol that will achieve that probability of detection. There are a number of trade-offs that can be made among the various elements of the monitoring protocol. For example, if searching turbines out to 120 m every 9 days achieves the same overall probability of detection as searching turbines out to 50 m every day, the former protocol might be less labor intensive and hence less expensive. In determining optimal sampling protocol, the level of overall detection probability required to provide evidence that a given target has not likely been exceeded is the same, regardless of the species of concern. But the level of effort/cost required to achieve that overall detection probability may differ greatly – e.g., other things being equal, dead eagles are much easier to find than dead bats.

CONCLUSIONS / APPLICATIONS

In the case of eagles with a permitted take of 1/year and an overall probability of detection of 70%, if we find one carcass this is not necessarily evidence that take has been exceeded. Even with an average take of 1/year, some years there might be 2 or even 3 taken, others none. We are working with U.S. Fish and Wildlife Service to develop a decision framework that would consider evidence from multiple years to help guide inference regarding exceeding take limits.

The Evidence of Absence approach (Huso et al. 2014) can be used both to inform post-construction monitoring design as well as to estimate the likelihood that actual fatality of a rare species did not exceed a pre-set limit. USGS has developed a user-friendly “Evidence of Absence” (EoA) software package and user’s guide to help managers design monitoring protocols [http://pubs.usgs.gov/ds/0881/]. It would be helpful to get feedback from industry about how this application is being used.

Manuela M. P. Huso, Daniel H. Dalthorp, David A. Dail, and Lisa J. Madsen *In press.* Estimating wind-turbine caused bird and bat fatality when zero carcasses are observed. Ecological Applications. http://dx.doi.org/10.1890/14-0764.1

Questions & Discussion

Q: ***You mentioned searching 120 m plots. Do you find it necessary to extend a search that far from the turbine base, even if it lowers the number of days searched?***

A: Typically no. As we go out from a turbine, we have belief and evidence that the density of carcasses drops off radically and rapidly. So generally, the bang for your buck is pretty low out there. Nonetheless, it might be an option to consider, if by searching out farther, you include 100% of the area in which a carcass might fall.

Q: ***What is the average distance you have found carcasses within plots?***

A: Not sure I have a good answer for that. In one study I’ve been involved with, we cleared out to 90 m (and still did not achieve 100% detection); what we found is that you have to go out about 45 m to get 50% of the bat carcasses – but that is based on one site in the Midwest, and I’m not sure how it applies anywhere else.

Q: ***We heard that in one study, half of all Golden Eagle fatalities were found incidentally. Does your model of optimal search protocol include the option to include incidental (non-systematic) observations?***

A: No, not really. It is possible but quite difficult to come up with the detection probability that accounts for incidental finds. Our model did not try to do that. However, incidental finds can certainly serve as a lower limit on fatality estimates.

Q: ***Indiana bats have both low expected take and low detection probability – how do we resolve this and still be able to afford the monitoring?***

A: There might be ways to do it. We would need to continue our statistical research to assure us that the estimates that we come out with using simple road-and-pad searches are still unbiased and meaningful; if so, we could develop some inference from searches that are economically feasible, and that can be carried on for much longer periods of time.

Q: ***Is the Service actually using the absence of evidence software for mitigation required for Eagle Take permits when survey data is insufficient?***

Christy Johnson-Hughes (Service): I know we're doing it for bats.
Robert K. Murphy (Service): We're in transition right now from post-construction monitoring (a component of the ECPG) to include some of the approach that Manuela has described.

Q: ***Given that the probability of finding zero common species is different than the probability of finding zero rare species, can priors be changed for common species as well as for rare species?***

A: The prior is not on probability of finding it, it's on the belief of what mortality actually is. So, yes, we could with information; if we have a belief, we could use reasonable informative priors, depending on the species.

Estimating fatality rates: finding the right denominator

Presenter: Douglas H. Johnson, U.S. Geological Survey, Northern Prairie Wildlife Research Center

PROBLEM / RESEARCH NEED

Every bird dies eventually, whether of natural causes or from anthropogenic causes, both direct and indirect. From an evolutionary standpoint, anthropogenic mortality is relatively new. How many birds die from these causes – and which species are the most vulnerable?

A comprehensive analysis of small-passerine fatalities from collision with turbines at wind energy facilities (Erickson et al. 2014) attempted to answer these questions, but fatality searches at wind facilities have several shortcomings:

- Spatial incompleteness – not every wind farm is searched, and where searches are conducted, typically not all the turbines are searched, and only a certain area around turbines is searched
- Temporal incompleteness – searches are conducted over limited periods, at widely ranging intervals (from daily to 90-day intervals)
- Incomplete persistence of carcasses – carcass removal studies attempt to correct for this, but they too have their limitations
- Incomplete perceptibility – searcher efficiency varies and depends in part on many other factors – including the type of substrate and the species involved.

Various statistical adjustments are made to account for these shortcomings, but all of them rely on questionable assumptions and on small, site-specific data sets. Moreover, not all fatality data that is collected is publicly available. AWWI is building the Research Information System

(RIS), a first-of-its-kind initiative, which will securely house wind-wildlife data and make it available for scientific analysis.

Objectives

Once we come up with an estimate of the number of birds killed by wind turbines, what is the appropriate context – or denominator – for that number?

APPROACH / FINDINGS

For statistical purposes, candidate denominators include:

- Capacity of turbine (MWs);
- Actual output of turbines (but this information is often proprietary);
- Other options – rotor-swept area, hours of operation, or hours of operation with high bird/bat activity – or in the case of bats, hours of operation during low wind speed periods.

From a biological perspective, candidate denominators include:

- Wind-related fatalities of other species;
- Size of species' population – allows us to calculate the proportion of the population estimated to be killed per year;
- Number estimated to be killed by other sources (e.g., for each bird killed by a wind turbine, for example, nearly 4000 are killed by cats)

Using natural (background) mortality as the denominator gives us a measure of "vulnerability" – the estimated difference in a population due to additional anthropogenic mortality:

Population change from one year to next

N_{t+1} = Survival rate*N_t + "Birth" rate*N_t

= $S*N_t + B*N_t$

= $(S + B)*N_t$

Under natural conditions, $(S_n + B) \sim 1$

(stationary population)

While we rarely know the natural survival rate, we can get some approximation based on related known variables:

- "K selected"
- "Slow" life history
- Body size
- Age at first reproduction
- Number of offspring (inversely)
- Size of offspring
- Parental care and investment
- Stable habitats and population size

CONCLUSIONS / APPLICATIONS

Concern for wind energy-related fatalities increases as vulnerability increases and population size decreases.

Can we estimate fatality from carcasses observed only on roads and pads?

Presenter: Joseph Maurer, *Oregon State University*

Co-Authors: Manuela Huso, Daniel Dalthorp (U.S. Geological Survey)

PROBLEM / RESEARCH NEED

In estimating fatality at wind power facilities, we generally focus on two primary sources of imperfect detection: 1) carcasses are removed before sampling, and 2) carcasses present in the searched area are missed by observers. A third source that is often overlooked is that carcasses land in unsearched areas.

Objectives

We focus on the question of unsearched areas with the objective of evaluating the potential for estimating total site fatality from carcasses observed on roads and pads.

APPROACH

We considered three estimators, all of which have been suggested in reports or in the peer-reviewed literature: an empirical method (the "cake" estimator); a parametric model estimator (density weighted proportion, or DWP); and a ratio estimator. Each of these estimators provides an algorithm for calculating total fatalities based on fatality searches conducted only on roads and pads (R&P). How the estimators work from a statistical stand point is not the emphasis. The most important idea to keep in mind is that the "cake" and DWP approach involve only searching R&P. The ratio estimator has the added cost of removing all vegetation in the fall area for a subset of turbines, which is costly and not always possible.

Cake Estimator

Search all roads and pads, then partition by distance for each distance divide the number of observed carcasses by the proportion of area searched. For example, if two carcasses were observed at 19-20 m from the turbine, and if road and pad constitute 10% of the total area at that distance, we would estimate that 20 carcasses would be found at that distance.

Density Weighted Proportion (DWP)

As with the cake estimator, this method involves searching all R&P and partitioning by distance. We then fit a generalized linear model (glm) on observed counts by distance, use this model to estimate the fall distribution, and use the distribution to obtain an estimated weighted proportion contained in R&P. The observed total is then divided by the weighted proportion to give us the percentage of all carcasses which fall in the searched area.

Ratio Estimator

Search all R&P. Take a sample, *S*, of turbines, then clear and record total fatalities for turbines in *S*. Estimate the ratio of fatality on roads and pads to total fatality, and multiply all fatalities found on the R&P by this ratio.

To test these estimators under different conditions, we took the R&P fatality data from four wind facilities (Fowler Ridge in Indiana, South Chestnut and Casselman in Pennsylvania, and Manzana Wind power project in Kern County, California) and ran through several different types of simulations, a thousand trials each. Please note the only information used from these facilities is the road and pad configurations; the number of fatalities in the simulations in no way reflects the true number of fatalities for any wind project listed above. The goal of the simulations was to see under what realistic conditions, if any, the estimators produced statistically poor results:

- Goldilocks Simulation – Assumes the distribution of fallen carcasses is isotropic – that is, that density is a function of distance, and that bearing (direction relative to turbine) is not a factor. Average carcasses per turbine is 100. Model used to assign carcass distance is from a fitted curve based on real data from Huso and Dalthorp 2014. Each of the following have one condition that separate them from the Goldilocks simulation:
    - Low Rate – Assumes a low rate of fatalities (simulated two carcasses per turbine on average).
    - Distance Distribution – Assigns distance using a non-parametric spline (ugly-looking function) based on a ballistics study from Hull and Muir 2012.
    - Anisotropy – Assumes the distribution of fallen carcasses is anisotropic – that is, that probability now depends not just on distance, but also on direction from the turbine; carcasses are twice as likely to fall south of turbine where they are also relatively more dispersed.

FINDINGS

In the Goldilocks simulation all of the estimators are relatively unbiased, but the ratio estimator has wide variability. Preliminary results suggest the cake and density weighted proportion methods may be preferred when rates are low, as the Ratio method's bias becomes more apparent – and it does not always produce an estimate – when rates are low.

However, the ratio estimator may be preferred when rates are high and strong anisotropy is present but unaccounted for by the other methods. Both the cake and DWP estimators assume an isotropic distribution of fallen carcasses around the turbine. (Cake assumes for each distance the observed and non-observed areas behave similarly; and the DWP approach models the fall distribution solely as function of distance.) Thus both of these estimators are biased if the fall distribution is anisotropic.

In the distance distribution simulation, DWP is a slightly biased estimator even though the glm poorly approximates the function used to assign distance.

CONCLUSIONS / APPLICATIONS

Given the simulation results, we considered strategies for reducing estimator bias.

The ratio estimator could be made better by increasing the number of turbines we clear, but clearing a 200-m plot around a turbine is expensive and not really practical. Also, detection probability is even lower in cleared areas, so that would also need to be taken into account.

The cake and DWP estimators are biased in anisotropic conditions. A future direction for research would be to come up with a way to adjust the DWP and cake methods to account for anisotropy while retaining the low standard error.

Questions & Discussion

Q: ***On the DWP method, if only roads and pads are searched, search area as a function of distance is most likely not uniform. How do you estimate density as a function of distance given the unequal search area? Seems like a circular problem.***

Manuela: The models take into account the fact that the area searched is a fraction of a particular ring. Density decreases with distance from the turbine, both because there are fewer carcasses the farther you get from the turbine, and also because you are searching a smaller fraction of the area at that distance. For the statisticians: the underlying glm used in fitting the model is a Poisson regression and one has to offset by the log of the total area searched for each distance; this accounts for the unequal search area.

Q: ***Can the "cake" estimator be improved by weighting by expected anisotropic distribution? Would this require a pilot study to determine where carcasses fall or are there consistent patterns across wind farms?***

A: When it comes to looking for consistent patterns across windfarms, one of the advantages we see with the DWP approach is potentially collecting enough evidence to where we can assume a fall distribution before we ever go out and sample. In terms of the cake estimator, the main advantage is that it is completely empirically based on the data that you find. As for improving the cake estimator by weighting expected anisotropic distribution – I think it would be a stretch to assume you could know the anisotropic conditions at a wind facility and defeat the purpose of this purely empirically based method. One approach that could account for anisotropy is to partition the search areas into quadrants and distances instead of just distance.

Q: ***Why was detectability of carcasses lower in cleared areas? Was this consistent across all of the projects you looked at?***

A: This was from the report at Fowler Ridge, where estimated searcher efficiency was 30% for cleared areas, but closer to 80% for roads and pads. (Wally notes: 30% is better than for non-cleared portions of plot.)

Q: ***Do you see road and pad searches becoming the new norm for post-construction monitoring? Or are full-plot searches still needed to compare findings? (Or a hybrid approach?)***

A: It depends on the rate of fatalities. If rates are high enough, we can get accurate enough estimates by searching only road and pads. I could see the potential for making that the norm.

W. Erickson: Part of the reason we did cleared plots wasn't necessarily tied to the ratio estimator, but it was the "smell" test – because we were sampling pretty small areas around each turbine, so the idea was to clear a larger area to get a better idea how well we could estimate fatalities from a road-and-pad search.

Comparison of avian mortality sources and evaluation and development of compensatory mitigation options for birds

Presenter: Wallace Erickson, Western EcoSystems Technology, Inc.

[presentation]

Co-Authors: Paul Rabie, Kenton Taylor, Kim Bay (WEST, Inc.)

PROBLEM / RESEARCH NEED

The vast majority of birds in the U.S. are protected by the Migratory Bird Treaty Act (MBTA). The MBTA prohibits the taking of migratory birds, their eggs, parts, and nests. In spite of the federal protections provided to migratory birds under the MBTA, estimates of anthropogenic (human caused) bird mortality in the U.S. indicate that billions of birds die each year directly or indirectly from anthropogenic causes.

More recently, some industries including wind and solar have either voluntarily agreed to or were required to compensate for migratory bird mortality from their activities. For example, a solar company agreed to contribute over $1 million to conservation programs and activities to benefit migratory birds. A wind company, in a settlement with the government over bird mortality at a wind project agreed to contribute money for bird conservation.

However, having tools available that can provide direction on the benefit of those activities and mitigation money is needed. In some cases, considerable resources are spent monitoring the impacts to migratory birds (e.g. the impacts of wind energy development on passerines) with little (if any) actual benefit to the birds. Results of many of these studies are consistent and might have been predicted with reasonable certainty without the additional monitoring data by using existing data from pre-construction studies and possibly other monitoring data. Resources may be more wisely allocated by funding compensatory mitigation approaches that provide an actual measurable benefit to migratory birds in the U.S.

<u>Objectives</u>

Develop resource equivalency analyses (REAs) to quantify the benefit to birds of compensatory mitigation approaches, along with associated implementation costs, to facilitate a cost-benefit analysis between the various options.

<u>APPROACH</u>

We researched and have begun developing resource equivalency analyses (REAs) for several compensatory mitigation approaches for migratory bird types or groups. One approach to resource equivalency modeling utilizes mortality estimates for a species from one activity – e.g., wind energy facility operation – and calculates the cost over project life in species years, and then calculates the extent/magnitude of a given compensatory mitigation measure needed to "create" an equivalent number of species years.

For example, given a mortality estimate of 1 eagle killed at a 100-turbine wind facility over 30 years, it would require retrofitting approximately 9 utility poles for 30 years to "save" an equivalent number of eagle years (slide #6) assuming 30 years of retrofit life and using the USFWS model. Timing of the compensation must be taken into account – if the retrofits are implemented upfront, the present value of avoided fatalities (per pole retrofit, in this case) is greater than if pole retrofits are done at intervals or after the fact of an eagle fatality at the wind farm. In this example, a developer could commit to 9 pole retrofits upfront, or 13 retrofits at five year intervals, or a 15-pole "payment" when an eagle fatality occurs (slide #7) again using the USFWS model and a 30 year retrofit life.

Pole retrofits have already been acknowledged as compensatory mitigation for eagles, but could be developed as a benefit to other raptors as well since unsafe poles kill many raptor species. Other compensatory mitigation approaches that we have begun evaluating in a REA framework include: feral cat control programs, marking fences and overhead lines, lead abatement, carcass removal (from roads and highways), and marking power lines. We have also begun to look at how to equate increased prey from habitat enhancement to reproductive success of eagles or other raptors.

For evaluating feral cat control programs, we looked at cat predation rates from the literature. The removal of one female cat was equated to saving a few thousand to over 20,000 birds over the lifespan of the female cat and two generations of kittens.

FINDINGS

Based on our feral cat resource equivalency analysis, removing 1 female cat from an area, could save 2000+ birds, equivalent to 400 turbines at 5 birds/turbine/year. Although difficult to tailor this particular mitigation measure to species impacted, cat removal would have benefits to other wildlife, as only about 40% of the prey items captured by cats are birds.

Slide #18 summarizes estimated mitigation measure cost and "bird lives saved" benefit of cat removal and other mitigation options included in our resource equivalency analysis.

CONCLUSIONS / APPLICATIONS

The results of this research provide additional perspective on level of impacts from various sources on birds. REAs allow for more relevant comparisons of risks among mortality sources, and provide a smorgasbord of options for consideration of mitigation from those sources.

For songbirds, we recommend focusing resources less on additional fatality monitoring, which does not add much to our current understanding of impacts – focusing those resources instead on bird conservation and the biggest sources of mortality. We also recommend modifying study designs to be more optimal for target groups (e.g. raptors and bats), instead of suboptimal for all.

Questions & Discussion

Q: ***Are you aware of studies demonstrating the effectiveness of markers on tower guy wires?***

A: There is some literature out there, especially for water associated birds from high risk overhead lines. There are some studies going on in Southern California, looking more generally at arid areas – so there is some data, but not necessarily a lot of information.

Q: ***Can you speak to the assumption that one cat removed results in a minus one change to cat population – what about re-colonization or density-dependent response?***

A: We assumed no density dependence, so yes that could be an issue.

Q: ***What would be effect on the REA of including density dependence in your cat demographic model?***

A: Fewer birds saved.

Q: ***Are REA analyses being done for bats, and if so, what do they look like?***

A: Would have to talk to Cara Meinke, Scott Pruitt and others to get a better idea of that.

Q: ***How can regulators incorporate alternative REA into existing permit programs?***

A: FWS is trying (especially with eagles) to find alternatives to power pole retrofits. There is a lot of research going on, and I think we need some data to demonstrate what the value of the credits are. I'm hoping we can put some information together on the songbird side as well.

Q: ***Some REAs include the discount rate of (usually 3%) whereas others do not. Why?***

A: Economists picked that rate; I don't know the reason, but it's been a standard used with Natural Resource Damage Assessments (NRDA) as well as with the power pole retrofits.

Q: ***Where did the high-end estimate of $7,500 per power pole originate?***

A: I believe that figure was generated in California, when they were setting up fund for power pole retrofits – it included the cost of the retrofit along with an administrative fee and other potential fees.

WREN: International Approaches to Mitigating the Impacts of Wind Energy on Wildlife

Wind power: Ontario's approach to wildlife impact avoidance and mitigation

Presenter: Peter Carter, Ontario Ministry of Natural Resources and Forestry

[presentation]

PROBLEM / RESEARCH NEED

Presently there are over 60 wind energy projects operational in Southern Ontario, many along the shores of the Great Lakes. Another 45 projects are under contract, for a projected total of 2,625 turbines, about 5,300 MW. In 2009, the Green Energy Act was passed, including a Renewable Energy Approval (REA) Regulation designed to bring clarity to the requirements for protecting wildlife. This is critical for developers, because in Ontario, once you get a procurement contract, there is a 3-year window to get the project up and running; there is not much time for a lengthy iterative process.

Currently we are finding an average of 19 bat fatalities per turbine per year in Ontario, of which 70% or more are migratory bats. White Nosed Syndrome also is beginning to spread north and west across the province, and three bat species (little brown bat, northern long-eared bat, and eastern small-footed bat) are now listed as endangered. By contrast, we are seeing low levels of bird mortality (5 birds per turbine per year) at Ontario wind power projects. Bird habitat is a greater concern than direct impacts (i.e. collisions).

Objectives
The objective of this presentation is to provide an overview of Ontario's approach to wildlife avoidance and mitigation within the REA context, and to describe how the Ministry of Natural Resources and Forestry (MNRF) is collaborating with industry and scientists, academics and federal agency partners to advance our collective understanding of impacts of wind on wildlife.

APPROACH

The REA Regulation takes a wildlife habitat-based setback approach. The MNRF provides guidelines that can be used to determine whether a prospective project area includes significant wildlife habitat (and other natural heritage features). If the developer builds outside the 120 m setback from that habitat, no further effort is needed. If project elements are built within the setback, the developer must follow standardized MNRF evaluation, monitoring and mitigation requirements. This standardization allows us to compare "apples to apples," across projects, making meta-analyses possible.

Pre-construction monitoring is required to identify and evaluate bird and bat significant wildlife habitat (SWH), and to identify potential impacts and mitigation measures. Key post-construction components include: three years mandatory post-construction mortality monitoring at all wind power projects, and habitat monitoring where required; mortality thresholds (see below) trigger mitigation (including operational) measures, as well as additional monitoring requirements, depending on the species.

<u>Bat Guidelines</u>
The mortality threshold for bats is 10 bat fatalities per turbine per year. This is a "one strike you're out" threshold; if it is exceeded even once during three years of mandatory post-construction monitoring, a mandatory curtailment (5.5 m/s cut-in speed overnight during peak bat activity period July-Sept) is imposed facility-wide, for the duration of project, and three additional years of effectiveness monitoring are required. The 5.5 m/s cut-in speed has been shown to significantly reduce fatalities, albeit with some loss of energy production.

<u>Bird Guidelines</u>
Bird and raptor mortality is considered significant when annual bird mortality exceeds 18 birds per turbine per year at individual turbines or turbine groups, or 0.2 raptors per turbine per year across a project. Because it is easier to link bird fatalities to an individual turbine or cluster of turbines, mitigation measures are not required project-wide. However, an additional three years of effectiveness monitoring is required.

Ontario's 2007 Endangered Species Act prohibits the killing, harming or harassing of species at risk; and damage or destruction of species-at-risk habitat. Proponents of wind power projects that may affect species at risk during operation of a facility may seek an Overall Benefit permit, or:

- Register the activity with MNRF and take reasonable steps to minimize adverse effects to the species;
- Have an expert prepare a mitigation plan; and
- Monitor the effectiveness of the mitigation and submit monitoring reports.

For bat species at risk (SAR), typical mitigation plan components to minimize adverse effects may include: limiting unnecessary lighting; operational curtailment during times of day/year when SAR bats are most active; and progressively escalating mitigation if mortality continues to be observed.

Have developed a more flexible "rules in regulation" approach, whereby a proponent can register with MNRF and take steps to minimize adverse impacts to species at risk. These would include preparing a mitigation plan and five-year monitoring plan with annual reports. It's a proponent-led process that takes into account the level of risk, with agreed-upon mitigation measures escalating as risk of impact increases. (So, for example, a lower-risk project might require monitoring at only a subset of turbines.)

FINDINGS

We are now into year two of looking at post-construction data that's been collected using the standardized methods, and we also have some projects that have exceeded thresholds and are now collecting data on mitigation efforts.

Post Construction Monitoring Data: Wind Energy Bird and Bat Monitoring Database

Because our REA regulation requires standardized evaluation and monitoring protocols, we are getting really good "apples-to-apples information," including consistent post-construction monitoring data. Since 2007, Ontario MNRF has been partnering with the federal agency Environment Canada, CanWEA, and Bird Studies Canada (an NGO), to collect and maintain a database of this information (www.birdscanada.org/birdmon/wind/main.jsp).

We have been relying on a voluntary submission process from industry, and it has taken some time to gain trust regarding the confidentiality of the data. (The same field data collection sheets and data submission templates are being used in other parts of Canada as well.) This repository for mandatory post-construction monitoring bird and bat data enables broad-scale analysis of monitoring data – including site and turbine information, monitoring protocols, and annual summary reports with species composition, seasonal fatality patterns and so on – from multiple projects across Ontario and Canada. The analysis and reporting of aggregated data is going to allow us to develop a better understanding of effects of wind turbines on birds and bats, both in Ontario and across the country.

CONCLUSIONS / APPLICATIONS

MNRF has undertaken an initiative with its federal counterparts and CanWEA to look at the effectiveness of Ontario's wind power bat guidelines, and at the cost-effectiveness of the mandatory mitigation requirements, which were derived from research in other jurisdictions. We want to understand the effects of bat mitigation on Ontario's wind power producers and on the electrical system. It may be possible to refine mitigation requirements to target high mortality periods, address species-specific mortality risks, and improve the cost-effectiveness of the requirements.

MNRF has established research partnerships with agencies and academics to address knowledge gaps and improve wildlife management, including:

- ***Marine and weather radar research on bird migratory patterns*** - Identification of timing, concentration areas, and flight height in Great Lakes Region; increased mortality associated with lakes and other features has not been observed
- ***Identification of significant habitats*** - MNRF has identified locations of landscape features associated with increased risk (e.g., bat hibernacula) and enhanced the setbacks from these significant wildlife habitats in the guidelines.
- ***Movement of migratory bats across landscape*** - Peak migratory activity periods have informed timing of mortality mitigation; although specific migratory routes have not

been observed, bat migratory stopover ecology research has enhanced understanding of habitat use and timing in Great Lakes Region.

Questions & Discussion

Q: ***What is the wind-wildlife studies budget within your program?***

We are not a big ministry. We do have some budget, and we look for creative solutions, i.e., opportunities to partner with other entities that can provide funding or other resources.

Q: ***How far is the setback from significant wildlife habitat? If a project is outside that setback, what pre- and post-construction studies are required?***

We have a technical guide that identifies criteria for determining whether habitat is significant. So, for example, there could be a bat hibernaculum with a certain number of bats of a particular species using it; the tech guide determines the extent of the surrounding area that supports the hibernaculum – depending on the species it might be 1-2 km out from the hibernaculum – which is therefore considered significant wildlife habitat. Our regulatory approach requires a setback of 120 m from that identified area.

You need to evaluate the habitats that might be within your project location, determine whether they are significant. At that point you can site your project beyond the setback and avoid any further work, or you can propose to move within that setback – or within the habitat itself – because you don't think you're going to have an impact. In the latter case, you have to have an environmental effects monitoring plan on the post-construction side to monitor the habitat to make sure you are not having an impact, or mitigate if you do.

Questions submitted but not addressed during the session:

Q: ***Is there any possibility of combining efforts between the BSC database and the AWWI database?***

A: BSC and AWWI have discussed and shared database development experiences and objectives. There has been no discussion of combining efforts at this time.

The challenges of verifying mitigation measures in-situ

Presenter: Bjørn Iuell, *Statkraft, AS, Norway*

[presentation]

PROBLEM / RESEARCH NEED

Norway, and specifically Statkraft, is the largest producer of renewable energy in Europe. The vast majority of our total generation (60 TWh in 2012) comes from hydropower, but we have significant investments in wind generation as well. Last autumn we opened Sheringham Shoal, a 317 MW project in the North Sea, capable of providing 220,000 British homes with energy. As the Senior Environmental Advisor for Wind Power & Technologies at Statkraft, I am responsible for coordinating and funding research for our on and offshore locations.

The Smøla wind farm, in operation since 2002, consists of 68 wind turbines with yearly production of 450 GWH. The Smøla archipelago holds the densest population of White-tailed Sea Eagles in Europe (45-50 breeding pairs). The potential for collisions was pointed out in the environmental impact assessment, but ornithologists initially were more concerned about habitat destruction than about collision.

In 2007, the BirdWind project was established to research the problem with support from the Norwegian Research Council, and in cooperation with Energy Norway, Norwegian Water Resources and Energy Directorate, the Norwegian Directorate for nature management, RSPB, NERI and others. With a budget of about $3 million (US), BirdWind incorporated a wide range of approaches, including: desk-top studies, fatality searches, radar, GPS/GIS, behavioral studies, camera surveillance, DNA analysis, mortality and population monitoring. The program was completed in 2010, although fatality data are still being collected.

One of the methods used was to equip Smøla nestlings with GPS transmitters, and track the movements in relation to gender and year of life from their birthplace to fatality. Slide #10 maps the movements of a male tagged at Smøla (green dot) in 2009. Blue dots track its movement during the first summer, and red dots track its second year positions until its death at Lake Lossen (unrelated to wind turbines) in 2011. Slide #11 compares female v male eagle movement in terms of distance from the nesting area over time. Females move more than males during the first summer, but then during the second year of life, males are covering greater distances. They come back to Smøla in October, hence a secondary peak in activity and fatalities. BirdWind also found that there are Willow Grouse colliding not with the turbines but with the towers.

FINDINGS

To date the wind turbines at Smøla have killed a total of 59 eagles, including two Golden Eagles – about six per year on average. Collision fatalities peak sharply in the spring months when bird activity also increases.

In 2014, graduate student Espen Lie Dahl confirmed that the White-tailed Eagle population at Smøla is affected by disturbance of habitat as well as by collision mortality. Dahl found that eagles did not significantly change their flight behavior when inside the wind farm, possibly explaining the relative high collision mortality. He also found that territories close to the wind farm experienced reduced breeding success in the post-construction period compared to pre-construction. The effect was due to mortality and birds being displaced from their territories within the wind farm.

While the growth rate in the population was reduced by the wind farm development, particularly for parts of the population breeding close to the wind facility, the eagle population in the area as of 2014 still has a positive growth rate (1.02). One breeding pair could have multiple breeding territories. Floaters also help to keep the population genetically diverse.

CONCLUSIONS / APPLICATIONS

Smøla is wonderful laboratory for this kind of research. In 2013, Statkraft in partnership with Vattenfall, Statoil, TrønderEnergi Kraft, Energy Norway, NINA, NVE, and NRC has launched a four-year study of bird behavior near the turbines. INnovative Tools to reduce Avian Collisions with wind Turbines (INTACT) is a relatively low-budget effort (about $1.5 million US) that will use a DTBird camera system, along with radars and GPS.

A first stage of INTACT is a review of the literature on post-construction mitigating measures to reduce collision mortality, evaluating the efficacy of 26 different mitigation measures based on what we know about the sensory and aerodynamic ecology of birds, as well as their cognition and behavior (in press – 2015). Slide #18 illustrates how the mitigation measures are scored on the basis of six criteria, based on tests of the various measures that have been conducted in different parts of the world.

We are using Merlin radar to track bird movements within the wind farm, as we test measures that show promise for use at Smøla:

- Painting rotor blades (motion smear pattern) to make them more visible
- Marking turbine towers to help willow grouse avoid collision.
- UV lighting (no data yet)
- Audible deterrents

Data will be collected before end of 2016.

Questions and Answers / Discussion

Q: *We've come to learn that Altamont is not representative of avian impacts at all wind resource areas. How representative is Smøla?*

The average "take" at Smøla wind farm is 0.1 eagle/turbine/year – it is a completely flat island, and there is no behavioral response to the wind farm. On the neighboring island Hitra, the average outtake is half what we see at Smøla. The population density at Hitra is lower than at Smøla and the Hitra wind farm is located on a hill; we suspect that the different bird behavior is due to different topography. So we think that Smøla is not representative of wind farms (in coastal Norway, at least), but more of a worst case.

Q: ***Is there any attempt at species identification with the radar/camera detection system, or are all tracks considered to be White-tailed Eagles?***

A: I cannot answer that. The only fatalities we are finding are White-tailed Eagles and Willow Grouse. I don't know if the researchers are able to adjust their detection systems to pick up only eagle tracks.

Question submitted but not addressed during the session:

Q: ***You mentioned reputation being an important factor in Statkraft's decision to mitigate. Is the pressure coming from the public?***

A: Initially there was a strong opposition against the establishment of the wind farm, mainly from the ornithologists. This led to the formation of the R&D project BirdWind (2007-2010). The media attention has dropped since then. The main driver for us now is our own internal environmental policy.

Mitigating the impacts on seabird and marine mammal populations from 4GW of offshore wind farms in Scotland

Presenter: Finlay Bennet, *Marine Scotland Science*

[presentation]

PROBLEM / RESEARCH NEED

The Scottish government has established the goal of meeting all of our electricity needs from renewable energy by 2020. This is a very ambitious goal, and offshore wind is an important piece of the strategy. The North Sea is a busy place for wind energy. We take a broad definition of mitigating impacts, with a focus on strategic planning at the project assessment/licensing stage. Much of this planning was done six years ago, but we have learned a lot since then. The most important strategy for avoiding wildlife impacts has been to go further out, away from the coast.

Objectives
Our objectives are to:

1. Mitigate conflict between renewable energy and wildlife populations;
2. Use a modeling framework to both assess and mitigate collision, displacement, and barrier effects.

APPROACH

This presentation focuses on the cumulative impacts of eight offshore projects in two clusters; each project is about 500 MW in size. We used multi-colony tracking to reveal the winter distribution of the Black-legged Kittiwake (slide #4), a bird that breeds in Scotland but may spend part of the winter on the North American sea coast.

There is no way to entirely avoid impacts, so how do we minimize them? Regulators tend to ask for worst-case scenarios. These clearly would be unacceptable, but then the question becomes, what level of impact is acceptable? To answer this kind of question, we need to understand the population consequences – to look at underlying population trends and the duration of effect. In the case of seabirds, we are seeing declines driven by decreased food supplies for seabirds resulting from ocean biological change (resulting from climate change).

Slide #9 shows observed seabird population trends over the past 30 years, along with predicted trends assuming no change in adult survival and productivity. We modeled how collision, displacement and barrier effects might affect these vital rates, taking account of natural variability as well, and from that try to estimate the extent to which the population can be expected to tolerate those effects. We created an iterative modeling process to more accurately estimate effects and also to give us a basis for developing mitigation measures at the planning stage.

Collision Risk

The developers have density estimates for all our seabird populations, which can be fed into a collision risk model. However, we also have flight height data for our seabird species, from which we can deduce that collision risk is not uniform over the entire rotor-swept area. The extended "Band" collision risk model (slides #11 & 12) makes use of flight height distribution data to show us how relative collision risk varies with turbine clearance height (above sea level) for different seabird species.

Displacement/Barrier Effects

We made some fairly simplistic assumptions about displacement rates, using telemetry data and looking at the time and energy budgets for birds' foraging trips to and from colonies. We then modelled body mass change resulting from changes in energetic cost for adults during the breeding season (slide #14), and combined these results with known relationships between: 1) body mass change and adult survival rates; and 2) foraging trip time thresholds and chick survival rates.

FINDINGS

Based on these analyses, developers were able to come back to us with mitigation options:

1. Collision Risk
    a. Fewer, larger turbines (e.g., greater impact from 100 3MW turbines than from 50 6 MW turbines)
    b. Increasing hub-height above sea level – significantly decreases modeled collision risk for Kittiwake
2. Displacement and barrier effects

a. Where strong barrier effects were identified, a project developer was able to significantly reduce this effect by removing just two turbines from the outer edge of the project.
b. Fewer, larger turbines was assumed to reduce displacement rates.

CONCLUSIONS / APPLICATIONS

The next stage of our work is to find out if the assumptions we've been making are valid, particularly in terms of whether the mitigation measures suggested by the modeling are in fact working, or even necessary in the first place.

There has been a lot of collaborative effort in Europe to answer offshore development questions. The Offshore Renewable Joint Industry Program (ORJIP - slide #17) includes four priority research projects, including avoidance rate monitoring at existing sites to improve collision risk assessments for sensitive bird species, and several projects focused on evaluating impacts of (and developing effective mitigation measures for) noise disturbance on marine mammals.

Questions & Discussion

Q: ***Why do you feel your collision risk assessment is not satisfactory – what improvements do you feel are needed?***

There are advances that we've made – flight height distributions are especially important offshore, because flight height is commonly skewed towards sea level. Collision events are relatively rare, so we have to think about them as stochastic events; we need to think about how we find out what are the environmental covariates that are driving that stochasticity, and incorporate those factors into the model, so that we can have more confidence that our models are making realistic predictions. Otherwise we are faced with a conservative approach that is constraining for everyone.

Q: ***Was the displacement you have seen (assumed) related to the moving turbines, or to the entire structure?***

I do not know the answer to that. The assumptions about displacement are based on data to some extent. We have surveys of changes of distributions of populations of animals, but the precise mechanisms that are driving those changes – how precisely animals are sensing the turbines – I'm not aware of any research on that.

Technology for Detection and Deterrence: Visual Sweet-Spots, Accelerometers, and Geofences

Conceptual basis of a lighting system tuned to the bird eye to minimize collisions with wind turbines

Presenter: Esteban Fernández-Juricic , *Purdue University*

[presentation]

Co-Authors: Bradley F. Blackwell, Travis L. DeVault (U.S. Department of Agriculture - Animal and Plant Health Inspection Service)

PROBLEM / RESEARCH NEED

Bird collisions with wind turbines are paradoxical given that birds are known for their high visual acuity. We often rely on trial and error to manipulate animal behavior – trying to attract a species to restored habitat, or repel a species from a dangerous habitat. This can be a very expensive approach in terms of time and resources.

Bird visual perception is very different from that of humans. It is characterized by high temporal processing, lateral vision, high acuity, and four rather than just three color dimensions. A better understanding of individual species' sensory system informs our ability to increase the visual saliency of an object from that species' visual perspective. This would allow us to improve birds' ability to detect turbines, thereby increasing the likelihood of avoidance behavior, and reducing the chances of collisions.

Objectives
This presentation discusses the conceptual basis of a lighting system tuned to the avian eye's visual "sweet spots" that can increase detection and avoidance of wind turbines.

APPROACH

This is interdisciplinary work that starts with an understanding of the visual physiology of the animal. The visual physiology information is then used to parameterize perceptual models, which are used to increase the conspicuousness of stimuli from the target species' visual perspective. Finally, we use these stimuli in behavioral tests to establish whether these stimuli are effective or not. This three-tiered approach allows us to determine:

- Light colors that are most salient to birds
- Whether lights are more salient when pulsing or when steady
- The distances at which birds can detect wind turbines with lights

- The flight positions that would increase or decrease the detectability of wind turbines with lights

In addition to identifying the visual sweet spots, we are developing an eye-tracker for birds to measure where the center of visual attention is projecting. This is helpful in thinking about where to position lighting alert systems.

FINDINGS

The promise of this approach can be illustrated by work that we have done to develop an aircraft lighting system that would enable Canada Geese to detect an aircraft in time to avoid it. We assessed the density and sensitivity of different photoreceptors in the goose's visual system, then tested our model prediction by flying aircraft with the lighting over a pen of geese. Geese became alert four seconds earlier – which could be enough time for animal to engage in avoidance behavior.

This testing relied on commercially available white lights, but we have also done some reverse engineering of the perceptual models to create lighting tuned specifically to the cowbird's visual sweet spot. Experimental testing showed that the cowbirds became attuned to the presence of aircraft with the specifically designed lights ten seconds earlier. In addition to identifying the light color with highest conspicuousness for a given species under different ambient light conditions, other design characteristics include the viewing angle, light pulsing rate and position in the wind turbine.

A word of caution is in order regarding the use of UV lighting. UV acuity in birds is very limited (Golden Eagles actually do not have photoreceptors sensitive to UV), and birds might actually be attracted to UV signals – that is, they may approach a UV signal in order to resolve it visually. Thus the use of UV signals, rather than helping birds to avoid wind turbines, might actually have the opposite effect of increasing collisions. This possibility needs to be tested empirically.

CONCLUSIONS / APPLICATIONS

Behavioral tests should be conducted to validate that the lights lead to avoidance behavior and tweak the light characteristics to enhance the degree of avoidance response. We propose to develop a light-based alert system with high visual conspicuousness for Golden Eagles but with low visual impact for humans. A light-based alert system could be coordinated with other remote monitoring efforts to use lights to channel Golden Eagle movements across areas with wind-power facilities. Overall, using this sensory ecology approach can provide a novel way of reducing collisions between birds and wind turbines.

Questions & Discussion

Q: ***How does the frequency of FAA red and white lights compare with what you know about birds' "sweet spot" – and has there been any demonstrated avoidance of lit towers?***

A: I believe the frequency that can be used for FAA lighting is around 2 Htz. The FAA is interested in trying to find a pulse rate that would appear to be flickering to a bird but not to a human, given birds' higher temporal resolution.

Q: ***In your presentation, we saw a comparison between the effect of lights designed for specific bird species vs. no lighting at all. What can you tell us about how the "sweet spot" lighting does as compared with other lights – for example, white light?***

A: White lights have equal representation from all parts of the visible spectrum. They are very prominent for humans, but may not have the same effect on birds necessarily. Obviously, we don't want to design a different light for every species. So we are trying to characterize the sweet spots of birds that are at high risk of collision, and then look for the overlap.

Q: ***If lights are deployed across an entire wind facility, what is the chance of creating a biological "dead" zone, preventing not just collisions but also use of the habitat?***

A: Birds are pretty smart. Our research with aircraft shows that birds will fly close by an aircraft – and provided they become aware of it in time, they can avoid collision. So I do not think that the kind of lighting we are talking about would cause birds to avoid the entire facility. The objective is to give birds more time to react and avoid, and our work with aircraft shows promise that we can accomplish this.

Q: ***Can you elaborate on the study that shows Golden Eagles do not perceive UV light (Doyle et al. 2014)? Do you expect this is also true for Bald Eagles?***

A: We would need to look at the gene sequences for the Bald Eagle retina. Right now we don't have enough comparative data across multiple bird species about photoreceptors to make generalizations about the sensitivity to different parts of the spectrum for different species.

Q: ***Are you doing any work with visual avoidance in bats? Is there a sweet spot sound frequency for bats?***

A: We don't work with bats, but we get this question a lot, so we're interested in them. In terms of the visual response, most bats have two visual pigments in the long and shortwave range of spectrum. In some species, the short-wavelength sensitive visual pigments gets down to the UV range. It would be very interesting to study this and understand it better. Three species of bats cannot see in color (would have to check the literature). So – bottom line – we don't know much, but the same techniques we apply to birds can be applied to bats to assess how they might react to a light.

Q: ***What are the current or potential costs of implementing these systems?***

A: There is no "one solution fits all" – more like having a set of additional tools that we can work with to create solutions. The beauty of biologists collaborating with engineers is that often what we know can be translated into applications using current technologies.

Question submitted but not addressed during session:

Q: ***Could your work with "sweet spot" lighting be used to minimize bird collisions with windows?***

A: Yes, indeed. But, we have not done anything on that topic yet.

Near real-time detection of avian and bat interactions with wind turbines

Presenter: Robert Suryan, *Oregon State University*

[presentation]

Co-Authors: Roberto Albertani, Jeremy Flowers (Oregon State University, School of Mechanical, Industrial & Manufacturing Engineering); Brian Polagye, Trevor Harrison (University of Washington, Department of Mechanical Engineering)

PROBLEM / RESEARCH NEED

Avian and bat mortality resulting from collisions with onshore and offshore wind turbines is a major conservation concern, guiding site decisions and driving environmental monitoring efforts. While carcass surveys are the standard protocol for quantifying mortality at onshore sites, this method is imperfect due to infrequent surveys at remote sites, removal of carcasses by scavengers between surveys, and delays of days to weeks or more in obtaining information on collision events. Carcass surveys are not at all feasible at offshore wind energy sites. Automatic detection and recording of bird and bat interactions – originally designed for offshore use, may also have real applications at terrestrial wind sites.

Objectives
Demonstrate that near-real-time detection and quantification of interaction rates is possible at both onshore and offshore wind facilities using an onboard, integrated sensor package with data transmitted to central processing centers.

APPROACH

We are developing and experimentally testing an array of sensors that will continuously monitor interactions, including impacts, of birds and bats with the blades, nacelle, and tower of wind turbines. We are interested in a wide range of impact kinetics, depending on species' size and weight, but also on whether the animal flies into the turbine (blade or tower) or is struck by a moving blade.

The synchronized array includes accelerometers, contact microphones, visual and thermal infrared spectrum cameras, and passive acoustic monitors. Accelerometers and contact acoustic microphones are placed at the root of each blade to detect impact vibrations and sound waves propagating through the structure. (Slide #6 shows the configuration of the sensors on and around the nacelle.)

On-board data processing algorithms using wavelet analysis detect impact signals exceeding background vibration. In the current design, stereo-visual and infrared cameras are placed on the nacelle to allow target tracking, distance, and size calculations. Image processing and blob detection algorithms identify moving targets within the camera field of view. Bioacoustic recorders monitor vocalizations and echolocations to aid in identifying organisms involved in interactions to the lowest taxonomic grouping possible.

Data from all sensors are temporarily stored in ring (i.e., circular) buffers with an adjustable duration of minutes to hours (slide #7). Detection of target presence or impact by any of the sensors can trigger the capturing of data for 10 seconds (vibration and image sensors) to 10 minutes (passive bird/bat acoustic sensors) before and after an event for transmission to an on-shore central data processing center for evaluation and post-processing. This mitigates the risk of "data mortgages" posed by continual recording. The duration of ring buffer storage and data transmission is variable depending on storage capacity and transmission efficiency. The monitoring system is designed to run continuously in parallel at several turbines in an array.

System tests were conducted using controlled, experimentally generated impacts on research wind turbines at the North American Wind Research and Training Center, Mesalands Community College, New Mexico, and the National Wind Technology Center, National Renewable Energy Lab, Colorado. In the field experiments, tennis balls weighing 50-60 gm were launched at the turbine blades from the ground and from the nacelle. (Balls were also soaked in hot water or filled with water to test thermal recording and impact signals for heavier objects, respectively.)

FINDINGS

Slides #12-19 illustrate the kinds of data output from the various sensor nodes.

Vibration node (accelerometers and contact microphones positioned at the root of the three turbine blades). Slide #12 shows the impact of a tennis ball striking a stationary turbine blade. This slide shows the signal from the 3 axes of one accelerometer, with the strongest signal in the out-of-plane axis. Slide #13 shows the high-impact strike of a ball hitting the blade of an operating turbine, as registered by both the accelerometers and the contact microphones. Note that there is some response from all three blades even though only one blade is being struck.

Optical node – In our system configuration, cameras were mounted looking downward from the nacelle. Species identification at the distance of the turbine blade length would require a camera with a narrow focal length (slide #17), and thus would require a lot of cameras to cover the rotor swept area. We are considering other placements for the cameras, including on the blade itself as shown in slide #18.

Bioacoustics node – Acoustic monitors also could be used as a trigger, but they are more intended to provide a more continuous time frame coverage of bird calls or bat echolocations prior to the impact event. The impact signal, however, can sometimes also be detected with these microphones (slide #19).

CONCLUSIONS / APPLICATIONS

Deploying a low cost sensor array will be instrumental during site assessments for proposed facilities, conducting impact assessments of established wind farms, and assessing efficacy of operational mitigation or deterrent technologies.

Questions & Discussion

Q: ***Will the vibration signal for a turbine be affected by the location of that turbine inside a wind farm? For example, will wake effects make it more difficult to capture a strike event?***

A: There certainly are a lot of factors that can affect the signature of a turbine, but those can be characterized and removed from background.

Q: ***Have you reached out to turbine or blade manufacturers about sensor placement in the blades?***

A: We have some industry representatives on our advisory panel and have spoken to some manufacturers. Placement of sensors is important. The technology keeps becoming cheaper and smaller. The accelerometers used in testing on turbine blades are large and would not be used in long-term deployments as is. For example, we use accelerometers weighing as little as 1 g attached to birds to study movement and flight patterns. Once we know which sensors to focus on, we can focus on streamlining the system, and ultimately the various types of sensors could possibly be integrated into turbine blades during design and manufacturing.

Q: ***In many cases we are most interested in the behavior of the species prior to or at the point of collision. Could your video system capture the birds not just on collision, but as they approach a collision event, so that we can learn more about their behavior leading up to the collision?***

A: Certainly it is possible; it’s a matter of where the cameras are placed and the detection algorithms used to extract and report the necessary data. If that is an important objective, it may make sense to have a completely separate but linked system that is looking at birds approaching the turbines.

Q: ***What are the current or potential costs of implementing these systems?***

A: Our system would be cost effective for industry if it:

- can provide needed information that they currently cannot obtain (e.g., offshore, or In dense vegetation where it currently is not feasible to conduct mortality surveys);
- is less expensive than sending technicians out to remote sites to search for carcasses; or
- could be used to strategically direct carcass searches on land if a turbine shows a single or multiple strikes.

Additionally, the system could be used to confirm that events are extremely rare by continuous monitoring of a turbine, since it can be difficult to confirm rare events with intermittent carcass surveys.

Collaborations are key to solve these technologically challenging problems. We are designing a proof of concept. To fully refine the system for commercial deployment will require collaborations from a wide variety fields of expertise in engineering and software development working along with biologists. We might find for example, that accelerometers alone are effective in detecting strike events (while also providing valuable information on turbine operation). In that case, many or all turbines could be equipped with these (some turbines already are so equipped for operational monitoring purposes, but usually recording at a lower frequency than needed for strike indication purposes) and only a sub-sample of turbines could be equipped with the full set of sensors.

Avoiding avian impacts with wind turbines using GSM/GPS tracking telemetry that incorporates autonomous geofence alerts

Presenter: James K. Sheppard, San Diego Zoo Institute for Conservation Research

[presentation]

Co-Authors: Andrew J. McGann, and Michael Lanzone (Cellular Tracking Technologies, LLC); Allyson L. Walsh, Michael P. Wallace, and Ronald R. Swaisgood (San Diego Zoo Institute for Conservation Research)

PROBLEM / RESEARCH NEED

The largest land bird in North America, California Condors once ranged from Canada to Mexico. After coming close to extinction they are now recovering and are expanding their ranges, including areas of existing & proposed wind energy development. Condors select habitats with strong and consistent winds to help them soar long distances while minimizing energy. They fly slowly, are not very maneuverable, and tend to be watching the ground while soaring, which increases collision risk. While there have been no definitive record of wind turbine impact injury to date, wind energy has potential to conflict with condor recovery unless collision risks are minimized.

Objectives

We report on a new GPS telemetry system for tracking free-ranging birds that transmits location data via the GSM cellular network and incorporates a custom geofence – a virtual boundary that can provide automated alerts and trigger curtailment in time to prevent collisions with operational turbines.

APPROACH

Condors are being reintroduced at sites in California and in northern Baja California. The Sierra ridge line provides both a wind resource and a north-south flight corridor between the reintroduction site and habitat in Alta California, and condors have been tracked flying through the site of a proposed wind energy site in northern Baja. The 155 MW Energia Sierra Juarez project includes 47 units of 3.3-MW Vestas turbines that will be operational in 2015.

We mounted telemetry tags on condors' wings at the Baja reintroduction site. Advances in miniaturization have brought the weight of these tags down to 45-50 gms; they can be configured either as a back-back or as a wing mount. Built with internal antenna, they are more durable and accurate than earlier telemetry devices. The GSM network enables greater amounts of more accurate locations to be collected from the telemetered birds and at a lower cost of data acquisition than traditional systems.

When the telemetered birds cross a virtual boundary, or geofence, an automatic alert system triggers various responses, including an early warning message to specified users and a change in the location fix rate. We use a reprogrammable duty cycle to generate more frequent reports (every 30 seconds) when the bird is inside the geofence; it returns to reporting every 15 minutes once the bird leaves this zone. Firmware can be updated remotely when tags are deployed.

The geofences can be established at a sufficient distance from a wind farm to enable time for turbines to be slowed or shutdown before a bird can fly to within potential collision range. Multiple geofences set at increasing distances around a wind farm can provide alerts of increasing urgency as a telemetered bird flies closer.

FINDINGS

We demonstrated the efficacy of this alert system using information derived from field trials and deployments on California Condors reintroduced in northern Baja site, whose movements take them within proximity of Sierra Juarez energy development site. Slide #33 shows a map of the proposed wind project, with geofence alert zones established at distances of 20 and 40 km from the project area. A condor flight path crossing the project area, based on telemetry data from a tagged bird, is also shown.

We used a helicopter following the flight paths of telemetered birds to conduct field tests of geofence automated SMS alert message response times. Location data from the tags were highly accurate (<2m) when tested against a sub-meter DGPS with GNSS driver. The average SMS response times after crossing the geofence boundary were approximately two minutes. It would take a condor cruising at 15 kmh over 2 hours to reach the closest turbine after the first alert, while a condor flying towards the project area at 100 kmh would not reach the closest wind turbine until 22 min after the first alert.

CONCLUSIONS / APPLICATIONS

Geofence contours can be set according to the flight speed of birds to ensure enough curtailment lead time. Field tests of the equipment are very promising, but there are some limitations of this approach to be considered.

- Birds must be captured and telemetered.
- The equipment is too heavy for smaller birds species and bats.
- The telemetry tags are powered by solar-recharged lithium-ion batteries, so only operational during the day.
- Cost is coming down, but still high –our cost was $4,500/unit plus data fees; costs have since come down to about $3,000 per unit including data fees.

Another consideration is what to do if tagged birds loiter within the project area. How long would operators be willing to keep turbines shut down until a bird departs? As an alternative to operational curtailment, the geofence system could be used to generate an uncomfortable but safe “buzz” when the bird traverses a geofence.

Future directions for research and development of this approach are:

- More field testing, multi-species deployments, fine-tuning and adaptive management.
- Integration of the geofence system into an automated shutdown system.
- Integration of the geofence system into a deterrent system.

Questions & Discussion

Q: *When the condors with the GPS tag flew across the proposed wind facility, what was its flight height?*

A: This bird was tracked flying between 142 and 358 meters above the ground when it likely intersected the ESJ wind farm.

Q: *Any plans to look at the geofence for other species, such as whooping cranes?*

A: Sure. This could be used with any bird that can handle the [50 gm] unit. Of course, you have to be able to capture the birds and fit them with tags – but the great thing is that the size and weight of these units keeps coming down.

Q: ***What are the current or potential costs of implementing these systems?***

A: The cost of the GPS units is not cheap, but prices are coming down.* If the system can be integrated into existing systems, that can also bring costs down.

* *The current price of the GSM-GPS geofence transmitters is $3K per unit, which includes an annual $300 data acquisition fee – down from $4.5K per unit plus data fees.*

Q: ***Any plans to look at the geofence for other species, such as whooping cranes?***

A: Sure. This could be used with any bird that can handle the [50 gm] unit. Of course, you have to be able to capture the birds and fit them with tags – but the great thing is that the size and weight of these units keeps coming down.

Technology for Detection and Deterrence: Advances in Imagery Techniques

A computer vision and machine learning system for bird and bat detection and forecasting

Presenter: Russell B. Conard, *Ornicept*

[presentation]

Co-Authors: Guanyu Zhou (Senior Engineer, Ornicept)

PROBLEM / RESEARCH NEED

Wind energy development has relied heavily on remote sensing techniques for meteorological resource assessment, but similar capabilities have not been available for wildlife assessments. Recent advances in computer vision and machine learning algorithms allow researchers to remotely identify birds by species and model their behavior. These computer science methods offer promise in species recognition, a capability essential for environmental permitting and operations that previously has been available only with human observers. (Computer vision and machine learning are both subfields of artificial intelligence and infer meaning from imagery and large data sets respectively.)

Automated detection methods have become increasingly important in the context of new regulations around wildlife impacts and the development offshore wind. Supported by the Department of Energy Office of Wind and Water Power Technologies, with collaboration from the National Renewable Energy Laboratory and Normandeau Associates, this project focuses on advancing software algorithms to integrate data from visual, acoustic, and meteorological sources to describe and forecast bird and bat activity.

Objectives

Specific objectives of this project are to:

- Identify birds by species in video, using an automated system
- Remotely operate computer vision sensor networks
- Build predictive models for avian and bat behavior in high-dimensional spaces – machine learning involving:
    - Multispectral Vision Data
    - Meteorological Data
    - Bat Acoustic Detections
- Deploy marine-adapted system offshore

This is a high-level overview of the current phase of research, a demonstration project being conducted at the Alta Wind Energy Center in Tehachapi, California, hosted by Terra-Gen Power. Preparations are being made to conduct offshore wildlife assessments using the technology with further development.

APPROACH

Given that wildlife protection enforcement is driving funding and new technologies, species identification really matters. In effect, some species – such as eagles – are “more equal” than others. As projects are increasing in scale and more remote sites are being surveyed, it becomes increasingly difficult to have people survey them.

Ornicept is a software company, so we buy off-the-shelf hardware wherever possible. Our focus is on the bird recognition, the predictive modeling and risk classification for birds. This presentation emphasizes the incorporation of actionable data and vivid imagery. (We do want to be transparent about the computer algorithms used, but this is not the forum for getting into those kinds of details.)

Teaching a computer to play checkers or chess is a relatively straightforward problem. But getting a computer to perform tasks involving visual perception is a much harder problem. Field collection of training data on raptors began in 2011. The training data consist of images of eagles in flight, taken from below with a high quality single lens reflex camera (slide #9).

The first step is to capture data from very high resolution video, which is fed into our system to extract content (images) that our algorithm can then identify by species. This requires fine-grain object recognition – detecting motion and then extracting targets from static and moving background information (e.g., clouds, turbine blades, insects). The next step is species recognition, using novel feature extraction methods derived from the training data set and machine learning algorithms for recognition. Finally, we do post-processing to determine characteristics like altitude, velocity, and trajectory, and to export a dataset that can be audited by humans to ensure quality control.

Video (slide # 11) shows an example of field-collected data that was collected at a hawk migration monitoring site that we used to collect significant quantities of training data. This example video is looking at examples of things flying overhead, and this particular example uses a Bald Eagle detection algorithm. In this case, the cameras were positioned by people to increase the likelihood of capturing targets. Some things cannot be distinguished readily; it is difficult to distinguish between two accipiters – for example, between a Sharp-shinned Hawk and a Cooper’s Hawk. It is within the scope of our algorithms to distinguish a Turkey Vulture from a Golden Eagle from an immature Bald Eagle. As the algorithms progress, we should be able to distinguish additional species.

To do predictive analysis, we have to incorporate meteorological data with the species data that comes from the cameras. We do some predictive classifications based on support vector machines. We worked with U.S. Fish and Wildlife Service, Holiday Beach Bird Observatory, the Hawk Migration Association of North America, and Hawk Mountain Sanctuary to get the migration data to train the model. In the future, we would hope to update the model using field collected data from the system.

FINDINGS

We bin the data, categorizing it into "fly," "no fly" and "mega-fly"), which – combined with weather forecasting data from NOAA – helps us to predict the level of migration activity we expect to see 24 hours later. We came up with very good results comparing model predictions with actual counts of Sharp-shinned Hawks at Brownstown in 2008 (slide #13). A second example (slide #14) compares model predictions with actual counts for Red-tailed Hawks.

Our forecasting model outperforms commonly accepted models (e.g., Hussell & Farmer; Bird Studies Canada) for forecasting raptor migration. It important to note that these previous models were focused on macro trends rather than daily movement.

CONCLUSIONS / APPLICATIONS

The forecasting is currently trained for migrating raptors. With additional data, we believe it could be trained for other species and that we could actually refine it to the behavioral level. We know that some behaviors are more risky around wind turbines, and we think that we could train the model to predict not just activity specifically risky types of behaviors, based on the types of weather that we see. Ultimately we'd like to be able to combine these models with the GIS-scale models other people have presented this week and be able to apply that information to new sites where we have very little data.

A Research Platform

With the support of DOE, Terra-Gen Power, Normandeau, and Renewable NRG Systems, we have established a sophisticated research platform at ALTA Wind Energy Center – including multispectral cameras, meteorological equipment and onsite computing servers. Having access to a permanent installation with such high-grade equipment is something that may be of interest to others. Academics and researchers from different institutions are welcome to apply for access to the system, to test models or do other collaborative work.

The research platform at the ALTA Wind Energy Center consists of:

- Full-scale multispectral recognition unit, with overlapping fields of view for visible, near infrared and thermal wavelengths, facing outward at a 45 degree angle from perpendicular
- Long-range detection unit that incorporates ultra-high resolution recognition with onsite computing power, and that helps advance development of background modeling and target differentiation models

- Meteorological sensor Integration is important for the forecasting component, and along with concurrent bird and bat acoustic detection systems will help us to do more advanced site modeling, incorporating both temporal and geospatial elements.

Long-term Implications

To be able to automate avian point counts – both onshore and offshore – and having risk models that are based on the site parameters will be very useful for siting. For threat detection, being able to tell the difference (in near-real time) between a Turkey Vulture and a Golden Eagle, especially at a site without human observers monitoring, is going to be very valuable. Finally, the ability to forecast a day ahead that significant hunting and foraging activity of a threatened species is expected, and that operations may need to be curtailed at a set of turbine strings, could help significantly with forecasting production.

Funding for Technology

One of the things we've learned in this work is that one of the first criteria that venture capitalists use in deciding whether to invest in a proposed technology is that it has the potential to serve a $1 billion industry. Moreover, from a venture capital perspective, bird and bat detection and deterrence technologies are considered independently – so that collectively, they would have to be serving an industry doing at least $4 billion per year of business to be considered "venture backable." As we see when we look to examples of other industries with high-risk, high-reward R&D, such as the drug industry, what this means is that Federal funding is critical. We would not have been able to develop and test this system without a DOE small business innovation research grant, as well as the support of Terra-Gen and our other partners.

Questions & Discussion

Q: Is it possible to identify species of birds in real time (less than two seconds)? In all weather conditions? Within 300-meter in all directions from the turbine? All at the same time? With what accuracy?

A: Real time is tricky – near-real time is more within reach. We use lower resolution video that's coming off the cameras initially, and at the same time we're storing the high resolution video. We run through support machines to get species ID, and we could maybe get it to 4 seconds (detection time, not warning time – which could be dramatically longer). But it's also looking at a larger viewshed in that case, and that allows you to have a more time. Experimentally we have the most experience with a camera facing overhead which is applicable mostly to surveying. We are actively working on long-range detection, in which you are looking horizontally and are able to pick things up that are much further away.

We use multi-spectral analysis to address all weather conditions. Thermal has good success in rain and snow. IR has much higher resolution than thermal, but it is impacted by weather. Visible performs very poorly in inclement weather, but they offer the most data. By combining all three of those, the goal is that machine learning models would benefit from the multi-spectral analysis and then we could use weaker classifiers during inclement weather. (Not all that optimistic about performance of visible spectrum cameras during poor weather, so that probably is a weakness of the system.)

What about 300 m, 360 degree – As Trevor pointed out, it's very difficult to get the amount of resolution that you need to do species identification. Goal would be to have side-scanning cameras positioned away from the turbines, looking at the rotor swept zone and beyond – perhaps something positioned at the edge of the wind farm looking out.

Q: Have you looked at any data that involves dense flocks? If so, how well can individuals be distinguished and species be identified with these technologies?

A: It's difficult to detect things that are occluded, so we have to constrain the problem by making some assumptions. One way to constrain the problem is by looking up rather than on the horizontal plane. If the targets occasionally separate from the flock, they can be pulled from the data separately.

Q: How long before systems ready for deployment at wind farms?

A: If 45 degrees off perpendicular is acceptable, we're close to that. And if you are looking at a finite set of species, for example, Golden Eagles, we could be deploying this system in six months. Horizontal scanning will take longer – that's probably a couple of years away. For doing survey work, looking overhead – even though the viewshed is smaller than human vision, and slightly underestimates mean bird use, it has the advantage of being able to gather data 24-7 – that capability is pretty close to ready.

<u>Questions submitted but not addressed during session:</u>

Q: Does Ornicept plan on developing the technology to also identify geese, ducks, or cranes?

A: The technology used to identify raptors is applicable across species of large, diurnal birds.

Q: Do you believe that [U.S. federal agencies – the FWS?] will allow wind turbines to be stopped for Bald Eagles but not for vultures flying towards the turbine blades?

A: It is important to remember that the USFWS makes most guidelines "voluntary," and it is up to the operator and the project's fiduciaries to determine their risk threshold. The exact operation of a technology based system would be similarly determined to the way that biomonitor based monitoring plans are implemented today. My understanding is that a number of these programs do incorporate species prioritization.

Automated analysis of thermal imagery for assessing the risks to birds and bats

Presenter: Shari Matzner, Pacific Northwest National Laboratory

[presentation]

Co-Authors: Valerie Cullinan, Corey Duberstein (Pacific Northwest National Laboratory)

PROBLEM / RESEARCH NEED

Observing the use by birds and bats of areas planned for offshore wind farms and estimating the interaction of birds and bats with turbine operation is essential to estimating wildlife impacts of offshore wind development. However, placing human observers at sea continuously is dangerous and extremely expensive. The use of thermal infrared (IR) cameras can safely enhance monitoring programs at a reasonable cost, as well as collect data during inclement weather and at night when human observers cannot work. As the use of IR cameras is increasingly being considered for offshore use, the need for algorithms to process video data to automatically extract relevant information has become critical. Combining remote sensing with automated processing reduces the amount of data that needs to be stored and transmitted, and produces quality information from the data that is collected.

Objectives

The objective of this project was to create algorithms that can extract and characterize the flight tracks of birds and bats from thermal video, generating statistics in a form that can be used to make decisions. Specific criteria were to:

- Produce reliable, verifiable information from remotely-sensed data
- Reduce the amount of data that must be stored, transmitted and reviewed by human experts.

This capability makes continuous observations of bird and bat activity over multiple diurnal and seasonal cycles feasible, which is valuable both for pre-installation studies and for post-construction monitoring.

APPROACH

A thermal camera works like an optical camera, except that instead of measuring reflected light, it measures radiated thermal energy. A video is a sequence of images called frames. An animal appears as a bright "blob" against a lower-energy (cooler) background; the shape is indistinct due to the uneven distribution of thermal energy. Automated track detection and characterization is conducted in stages (illustrated by a flow-chart in slide #6):

1. The first stage of our processing is a novel process called Video Peak Store (VPS), a technique used in radar video displays. A single image is generated from multiple frames by storing the peak value of each pixel over time.

2. Computer vision techniques are applied to the image to identify the contours of the bright objects by grouping pixels into spatially and temporally connected blobs.
3. The blobs are then connected into tracks using a scoring process to select the most likely track to which to assign each blob.

The result is a visualization of the flight track of an animal moving through the camera's field of view. The flight track provides more information than a detection alone, and the information can be output as a comma-separated value (CSV) file. The final stage of processing is the calculation of track statistics and features, a quantitative (machine-readable) characterization of the observations contained in the video. (Algorithms were implemented in C++ using open source libraries and are camera-independent.)

<u>Testing the Algorithm</u>

We generated a data set of several hours of recording using a protocol for making annotations in the field with an observer whose binoculars were aligned with the thermal IR camera's field of view. The observer identified targets that crossed his field of view as bird, bat, bug or other, using a customized laptop application. The observer could also make audio annotations about the flight path. Both video and field notes were reviewed by a subject matter expert to generate final annotations for evaluating the algorithm.

Track statistics, including object size and intensity, speed, sinuosity, and direction of travel, can be used by subject matter experts to infer animal type and behavior. (Slides #13 and 14 list the relevant statistics, how they are calculated, and what they are used to determine.) Two-dimensional images from a single camera are reported in pixels per second; the pixel size in meters depends on the distance, or range, between the animal and the camera. Slide #15 illustrates how the focal length of the camera and field of view enable us to determine that distance, which in turn allows us to calculate the speed of the target in meters per second.

<u>FINDINGS</u>

Slide presentation (slides # 8-11) includes two video clips, one of two bats, and one of several gulls, along with the corresponding VPS image of the bats' and gulls' tracks. The gull video shows multiple birds passing horizontally through the camera's field of view, with more birds visible in the distance. The algorithm does a fairly good job of tracking the targets, including birds flying in the field of view at a greater distance from those passing horizontally.

Based on human analysis of the video, the algorithms achieved an overall detection rate of 85.3%, and detected some animals that the human analysts missed in the initial round of annotations. The algorithms had a false positive rate of 15.6%, which was caused by erroneously splitting actual tracks into multiple tracks rather than by incorrectly labeling non-animal phenomena as flight tracks. Work is underway to correct this issue.

CONCLUSIONS / APPLICATIONS

Thermal IR video is effective both day and night (continuous observations) – and works in a wider range of weather than optical cameras. The processing algorithms we've developed extract the quantified, verifiable information – counts, estimates of animal density and temporal distribution of activity – that is needed to perform risk analysis.

An important advantage of the automated processing is that it reduces the total amount of data significantly: the development data set – 30 minutes of video containing 183 distinct flight tracks – was reduced from 416,431 kb of video to 63 kb of text track statistics.

Future work includes adapting the current implementation of the algorithms for near real-time operation, so that the track processing could be performed as video is recorded in a remote location, reducing data storage and transmission requirements. In the near term, we would like to make this software available to people using IR cameras to get their feedback. We also want to make our data available to others to use in benchmarking their data sets.

Questions & Discussion

Q: Is the technology you discussed more accurate or useful for larger birds than for smaller birds (e.g., passerines)?

Shari: It depends on the resolution of the camera you use, and also how far away the animal is. We can detect smaller birds easily, but not from as far away as we can detect a larger bird.

Q: Have you looked at any data that involves dense flocks? If so, how well can individuals be distinguished and species be identified with these technologies?

Shari: Video that captures multiple animals does present some challenges to our algorithms, but it's not impossible to do individual identification; it's just a harder problem. If you can identify a nearer individual, you can make some assumptions about the composition of the flock.

Questions submitted but not addressed during session:

Q: Do thermal cameras view accurately to distinguish a bird under conditions of snow? Rain? Fog? What about the limited number of pixels due to military laws?

A: Thermal cameras that operate in the mid-wavelength infrared (MWIR) are less sensitive to rain and snow. We don't have any recordings during those weather conditions, so we can't say for sure what the effect would be on bird detection. There are no laws that I am aware of that restrict the resolution of thermal infrared cameras.

Behavioral signatures of birds: an automated way to extract wing beat frequency and flap-glide patterns from thermal imagery

Presenter: Corey A. Duberstein, Pacific Northwest National Laboratory

[presentation]

Co-Authors: Valerie Cullinan, Shari Matzner (Pacific Northwest National Laboratory)

PROBLEM / RESEARCH NEED

Assessing bird and bat interactions with wind energy turbines is a permitting requirement, but it may be prohibitively difficult and expensive to do so offshore. Assessing risk requires us to assess presence and abundance of animals, flight heights and other behavior (e.g., avoidance). We need to assess whether the animal is a bird or a bat, a common v. a rare species, an endangered species v. a species of least concern.

The offshore environment is remote, dynamic – we cannot survey it in the same way as terrestrial wind resource sites. Development of a suite of behavioral cues into a signature that can be used to reliably identify an object from sensor data could enable automated data processing, relieving the burden of relying on human observers. Wing beat frequency and flap-glide pattern are two aspects of bird behavior often used by human observers as an indicator of species identity.

Objectives

Pacific Northwest National Laboratory (PNNL) is developing automated processes that use thermal imaging video data to:

- Allow the estimation of wing beat frequency
- Determine the flap-glide pattern

Shari Matzner's presentation focused on the automated track detection and extraction algorithm. Here we present how we analyze the extracted pixel group images to determine wing beat signatures and analyze that data for species identification purposes.

APPROACH

The work of Pennycuick (1996, 2001) and Bruderer et al. (2010) have provided a basis for categorizing birds on the basis of flight types and wingbeat frequency. Bruderer et al. measured 155 species, compiling 45 European species into four flight types:

- Continuous flapping: wading birds, waterfowl, auks, gulls, terns
- Soaring: storks, pelicans, large raptors
- Dynamic soaring: albatrosses, shearwaters

- Flap-glide: passerines, gulls, terns

Pennycuick's allometric model (slide #5) is pretty reliable for continuous flapping flight wingbeat frequency as a function of acceleration, air density, wingspan, wing area, and animal's mass.

PNNL has developed a parameter to measure the level of wing extension and a discriminant model to classify the wing position as an "up", "down", or "intermediate" position, based on the relative locations of the centroid of mass and a "hot spot" exhibited under the wing joint in images of birds in flight.

Pixel groups representing gulls in flight were extracted from frames within thermal infrared videos with the automated track detection and extraction algorithm described by Matzner. Birds in flight exhibit a hot spot under the wing joint near the center of the pixel group. Flapping of wings causes a change in shape of the pixel mass and a relocation of the pixel mass centroid. The relative location of the hot spot with respect to the centroid was used to establish wing position, and the standardized distance between the centroid and hot spot coupled with the relative size of the pixel group were used to estimate the level of wing extension.

Slides #6-9 illustrate the extraction and analysis process with thermal image data from 1.8 seconds of video of a gull in flight. From a series of thermal video images, pixel intensity values are extracted and the centroid of mass and hot sport are identified. Wing position is determined by the relative positions of centroid and hot spot. When the wings are up, the centroid is above the hot spot. In glide position, everything is flatter, and centroid and hot spot are in similar horizontal position. When the wings are down, the hot spot appears above the centroid.

Recognition of wing position within individual frames provides the necessary information to estimate wing beat frequency and characterize flap-glide patterns.

FINDINGS

Classification of the wing position on average was 91% accurate for wings up and down. Wings in an intermediate position were sometimes difficult to discern from wings up. Human observations of the wingbeat frequencies were within a half beat per second of the frequency extracted using the automated image processing.

CONCLUSIONS / APPLICATIONS

Automated extraction is possible and practical. It has the advantage of simplicity; the physics of flight is predictable. Wingbeat frequency does not change relative to the range of a bird. Wind speed and direction doesn't change the wingbeat frequency, though flap-glide patterns for gulls and terns might. Using the wingbeat frequency as a signature eliminates the need for acoustic detection. That said, wingbeat frequency is just one feature of behavior that may be used to classify object identity from a single visual sensor, and the ability to discern wing position depends on many factors, including camera resolution, wingspan of the animal, aspect angle of the animal, and its distance from the camera.

A lot of work has been done to classify European birds; we do not yet have all this information for North American species. From the literature, we can get wing areas and use the Pennycuick equations to establish wingbeat frequencies for North American species such as whooping cranes, eagles, and Pacific coastal birds. These classifications may not get us all the way to the species level, but they can get us to species groups; coupled with other information, this could be very helpful. Preliminary work looking at shape analysis also shows great promise.

Future signature discovery efforts include refining wing beat detection and measurement, object shape analyses, and inclusion of various data types from multiple sensors. Combining all these attributes has the potential to give us signature specificity at a level that can be used to assess risk, both for pre-construction studies and post-construction monitoring.

Questions & Discussion

Q: Is the technology you discussed more accurate or useful for larger birds than for smaller birds (e.g., passerines)?

Corey: With wingbeat signature the specificity of the flight pattern would lend itself to different species, both small and large. It depends on how unique the flight pattern is of the species of interest, compared to species of similar size that may be present.

Q: Have you looked at any data that involves dense flocks? If so, how well can individuals be distinguished and species be identified with these technologies?

Russell: It's difficult to detect things that are occluded, so we have to constrain the problem by making some assumptions. One way to constrain the problem is by looking up rather than on the horizontal plane.

Shari: Video that captures multiple animals does present some challenging to our algorithms, but it's not impossible to do identification; it's just a harder problem. If you can delineate a nearer individual, you can make some assumptions about the composition of the flock.

Corey: Keep in mind that we can distinguish in both space and time. As long as there is some separation in space and time, we can separate those.

Trevor: With stereovision, there is a correspondence problem. As long as you can pick out each bird with accuracy, you can figure out the length of the bird. In the case of a flock, you might just care about the general distance of the flock as a whole. But occlusion is an issue.

Q: How long before systems ready for deployment at wind farms?

Corey: We are still developing the signatures. Collaboration and combining data will allow us to test those signatures more quickly. We will have a better idea early next year.

Remote monitoring of birds and bats using visual and infrared stereo imagery

Presenter: Trevor Harrison, *University of Washington*

[presentation]

Co-Authors: Brian Polagye (Department of Mechanical Engineering, University of Washington), Robert Suryan (Hatfield Marine Science Center, Oregon State University)

PROBLEM / RESEARCH NEED

The quantification of bird and bat encounter rates with offshore wind turbines requires development of new remote monitoring techniques, as the accepted onshore method of carcass surveys is impossible in the offshore environment. There is no accepted method for continuous monitoring and quantification of near-field interactions (e.g., within 500 m of a turbine) – particularly collisions with the blades, nacelle, or tower – which is critical data for population modeling and environmental impact assessments. Ideally, we want a system that gives us continuous temporal coverage, under all weather conditions, and that gives us spatial coverage in all directions from the turbine – without giving up the resolution needed for species detection, behavioral observation, and species identification.

Objectives

The objective of this project was to evaluate the potential worth of optical detection methods for animal detection and identification, specifically comparing two optical sensors: visual and thermal infrared (IR). Criteria for comparison included temporal and spatial coverage, as well as practical questions of cost, computational demand, and hardware requirements. Specifically, we wanted to find out:

- What birds would we be able to distinguish at what distance?
- How accurate would our stereo IR system be in determining their position, velocity, and length?

APPROACH

A prototype optical node with both stereo visual and stereo infrared cameras was developed as part of an integrated near-field monitoring package, to assess the overall effectiveness of optical data for animal detection and identification. This system can provide both optical imagery and stereo information (e.g., target speed, length) for expert review. We are interested here in three levels of effectiveness – detection, behavior, identification, in order of increasing resolution requirement – and at increasing distance from the turbines. (We particularly care about the range out to 100 m, which represents the outer limit of a rotor swept area – the range at which species identification would be necessary for incidental take quantification.)

System specifications

Slide #9 compares the specifications for the FLIR A615sc thermal infrared and Manta G-210 visual cameras used in the prototype. (Ideally, all cameras would take images simultaneously, to avoid stereo timing errors that could lead to miscalculation of target length and velocity. This would require all cameras to share a common I/O trigger line – a hardware trigger. However, the FLIR camera model did not give us this option, so we had to use a software trigger. That is, program the camera to run at a given rate, and allow its own on-board clock run acquisition.) Note that the cost of a thermal IR camera is an order of magnitude greater than a comparable visual camera ($20 K v. $3K); this cost differential has to be weighed against the advantages of the thermal IR technology.

Computational demand is a non-trivial problem; visual color optical systems require extremely high bandwidth. Even a relatively modest system would produce over 20 TB of data per day if continuously saved – far more than we could hope to store, much less process. We resolved the problem of data storage and processing by using a ring-based 20-second buffer with an event-based trigger (slide #8). If no trigger event occurs, new data overwrites existing data in the buffer every 20 seconds. Ten seconds following a trigger event, data from 10 seconds prior through 10 seconds following the event is transferred to permanent storage. We used a manual trigger in the prototype, but can insert a software process observing and reacting to data streams to do it remotely. (Note this 'trigger' discusses recording of a full data set and is different from the hardware/software single image trigger discussed in the previous paragraph.)

Validated data sets

To evaluate the optical node, a series of ornithologist-validated data sets were collected at seaside locations on the Olympic Peninsula, Washington. We needed real data for characteristic pelagic species of sizes ranging from small (e.g., Marbled Murrelet) to large (e.g., Short-tailed Albatross) Specifically, we looked at:

- Barn Swallows: small, representing low altitude when foraging and high altitude when migrating
- Pigeon Guillemot and Rhinoceros Auklet: medium size, low altitude flyers
- Caspian Tern: representing small, mid-altitude flyers
- Glaucous-winged Gull and other gulls: medium, representing high and mid-altitude flyers
- Great Blue Heron: representing large mid-altitude flyers

Observations were conducted at ranges from 10 m to 300 m from the cameras, consistent with near-field monitoring needs for offshore wind turbines. The stereo imagery was processed to measure absolute bird size and velocity. Our goal was to share representative data sets with varying species, distance, and manually adjusted image qualities were distributed to post-hoc reviewers for validation. Unfortunately, this was not possible with our current data set due to the poor quality of visual imagery, which we felt would lead to an unfair and inconclusive comparison.

Stereo calibration

All cameras have intrinsic distortion. When quantifying pixel values, these distortions need to be calibrated. We do this by taking a series of images of a calibrated target, in this case, a meter by meter piece of aluminum, with a 10 cm x 10 cm grid pattern of paper squares. (For visual cameras, this can typically be a printed black and white grid.) We used an open source calibration toolbox for Matlab that provides corrections for the intrinsic distortions of each camera. The toolbox also provides a stereo triangulation calibration, taking a pair of calibration series for left and right cameras, extracting their extrinsic calibration. The output of this second calibration is a translation matrix which allows us to go from pixel coordinates to real world coordinates. (See slides #17-18.)

FINDINGS

The stereo imaging system was first tested by using it to detect and process information about tennis balls being thrown from the turbine nacelle at one of the blades (slide #19). Taking the ball's real positions, we used the distance between its positions in succeeding frames to calculate velocity, and took the real position's displacement within the frames to calculate length. The system calculated a length of 7.9 cm for a regulation 6.3 cm diameter tennis ball, a result of the software trigger timing error. (This is worst case result of system, and even so the length and velocity estimates are fairly reasonable.)

Slide #20 shows what the data looks like for IR thermal video of two bats, taken an optimal case of 50 frames per second. When the video is played, the bats' x, y, and z coordinates appear next to the target as it moves across the field of view. (Z is distance from camera, y is down.) The system calculated target lengths of 14 cm – a bit large for a local bat, but about what we would expect – again suggesting that, even using a limited computer vision toolbox, we came up with good results.

Slide #21 gives an example with a Brewer's Blackbird flying from right to left across the field of view. This is a bird flying at a distance of 81 m from the cameras, with a high standard deviation on the z (distance) estimate. At a less optimal rate of 12 frames per second, there is a greater timing mismatch, and the calculated length of the target (72 cm with a 33 cm STD) [*Author note:* There is an error in the presented slide. Measurements were actually 72 cm and 33 cm, not 0.72 cm and 0.33 cm]. Unfortunately, this is not very close to the actual length of a Brewer's Blackbird (20-26 cm).

CONCLUSIONS / APPLICATIONS

Preliminary results indicate the infrared cameras provide improved detection capability relative to visual cameras. It is clearly better in terms of temporal availability, lends itself well to automatic processing, and is promising for behavior analysis. It does not give us sufficient information for species identification, although we could make some assumptions using it in conjunction with acoustic data.

Weaknesses include cost – is the extra order of magnitude expense worth the extra data capabilities? At this point it seems unreasonable for this to be a commercial application. It is more likely to be a research tool for validating deterrence systems. Unlike radar, for example, stereo IR imaging can give us very high resolution data on bird position and quantification of collision events, and allow us to better observe animal behavior very close to the turbine blades where radar shadowing is an obstacle for radar detection of collisions.

Questions & Discussion

Q: How do you calculate the distance from the camera, given you don't know the real size of the object?

A: It's a function of pixel length; we can put the number of pixels and positions into the triangulation tool box and can get the real-world coordinates. (I can explain how that works offline.)

Q: Can you comment on the detection and processing effectiveness you would expect when operating the thermal systems at night – is the contrast enhanced, or would it also be attenuated by humidity and fog at night?

A: We definitely get a better signature in the evening. The animals' temperature doesn't change, while the night sky tends to be cooler. But yes, the signal is attenuated by humidity and fog.

Questions for All Presenters:

Q: Have you looked at any data that involves dense flocks? If so, how well can individuals be distinguished and species be identified with these technologies?

A: With stereovision, there is a correspondence problem. As long as you can pick out each bird with accuracy, you can figure out the length of the bird. In the case of a flock, you might just care about the general distance of the flock as a whole. But occlusion is an issue.

Q: How long before systems ready for deployment at wind farms?

Rob and Trevor: Another test of our full system in March or April at NREL wind energy test site, and that will conclude the proof-of-concept phase of development. From there to deployment will be probably 1-5 years; it's a matter of time and money.

Lessons Learned: Key Meeting Takeaways & Future Challenges to Address

Moderated by Taber Allison and Abby Arnold

We wrap up this meeting by giving participants a chance to talk about what they heard at this meeting, and what are some of the challenges that we need to be addressing moving forward.

<u>Key Take-away Messages</u> (Taber Allison)

- Abby started this meeting by giving us a retrospective over the 20 years that we have been meeting to share this research. It may seem like a lot of the same questions that were being asked 20 years ago are still being asked; but as a community we should take a pride in the enormous progress that has been made. These questions sound similar, but they have been refined, and we're narrowing down some of our concerns. We have brought in new techniques to help us focus and address these issues. We have seen an increased focus on minimization, using our technologies to improve our ability to detect, deter, and minimize impacts on wildlife. We are seeing enormous progress in applications of technology to these problems.

  AWWI held a technology innovations workshop in April 2014, where we brought together biologists, wind industry, consultants, and individuals representing "OEMs" (original equipment manufacturers) to stimulate conversation and coordination. DOE's EERE Wind and Water program has been very supportive of these efforts. We are seeing the results of efforts funded through DOE's market barriers program, and the work of the National Laboratories. DOE recently released request for information to learn about technologies to minimize collisions of birds and raptors, bats – that kind of support is really paying off in providing the kind of information that we need.

- At this meeting, we have seen requests for information sharing and the databases that are being set up to facilitate data sharing. This is critical to producing the kind of robust statistical analysis we need to predict impacts, given that we are dealing with relatively rare events, so the more we can aggregate data, the more statistical power we have to produce analyses we can use to make good policy. AWWI is populating its Wind Wildlife Information Center (AWWIC) with post-construction fatality data; the Service is enhancing its reporting system; the National Acoustic Monitoring database and North American Bat Monitoring program. I don't think duplication and overlap is a bad thing; it can be a good thing, as long as we are communicating with one another and leveraging the power of these efforts.

- We are seeing all sectors of the wind-wildlife community collaborating and communicating with one another, and this is very important. In putting together the program for this meeting, we jealously guarded the time we devote to hearing from scientists, both in the presentations and with the posters, because this kind of communication among the stakeholders and the people doing the research is what enables us to address these issues. AWWI is keen to continue to support and promote this kind of coordination.

Participants' observations and future challenges (Abby Arnold)

What can AWWI do through our outreach, and through the NWWC, that stakeholders who find these research meetings valuable would be willing to help fund when our contract with DOE phases out?

- Population sustainability for Golden Eagles – How do we reconcile population sustainability with maintaining local biodiversity?

- It's fantastic to see the international collaboration, so we don't double cost of coming up with solutions. Great to hear today's detection and deterrence presentations.

The NWCC has always tried to bring in the international community. We have been most successful when the focus has been on offshore wind. AWWI would love to work more with Canada, Central and South America, and Europe. Many of our 23 industry partners are international firms, as are several of our conservation organizations. I'd like to see AWWI do some kind of workshop focused on technology innovation in 2015, rather than wait until the 2016 research meeting – so please let us know if there is interest in that.

- It's great to have this forum as the field is rapidly developing. In terms of coordination, we could start to lead the effort more by focusing on refining the objectives. There was not much talk about how we can raise detection probability to be able to answer questions with more precision and accuracy. We leave it to policy makers to define objectives, and they tend to have a shotgun approach, asking questions like "what is impact on all birds?" that don't get us very far.

- As an electric & gas utility in Montana and S. Dakota, we have a renewable portfolio requirement that we are meeting, but we have these qualifying facility and community renewable requirements as part of that, and we are finding it extremely difficult to find projects in or near our service territory that have done any level of pre-construction surveys. We've got small developers trying to site facilities in areas that clearly are not appropriate from a wildlife perspective. Is there some way of doing outreach to those smaller, less pro-active developers.

We encourage you and others to approach AWWI; if we can put the funding together, we could put on workshops in Montana or other states where there is that kind of need.

- Research is always needed and welcome. Remember that we need to be testing and applying and improving existing technologies, not just waiting for perfect the technology.

We need to be testing and applying the technologies we have.

- This meeting provides an interesting perspective on this industry – much less adversarial relations among stakeholders than in recent past years. Better connection, very healthy, not sure what made that happen.

- The general public has no idea that this (meeting) is going on. Could do a better job of letting people know how hard this industry is working to do the right thing.

Each of you is our ambassador. We produce a proceedings, and AWWI puts out technical papers with our partners. But we are five people, so we need to partner with everyone in this room to get the word out.

- Part of what makes it possible for frank discussions at meeting like this is that we do not invite the press. That said, there could be some other efforts to publicize in the general press.

Good point; we do want to protect the conversation that takes place here on difficult topics. But we also need to come up with summaries and talking points that everyone here can use. The public needs to hear about this from people they trust.

- Partner with National Geographic! The technology is incredibly interesting, the types of research, could make for programs that the public would watch and learn from.

If people have contacts with National Geographic or another organization, please share them with AWWI!

- Need to recognize the companies that are actually implementing this. In publicizing this work, it is important to recognize the industry companies that actually are implementing the tools we have. They should get recognition and credit; people should not be led to assume that all wind facilities are doing this.

- There is a short video about the migratory movement of Indiana bats – fits in well with doing education of public about what we're doing: https://www.youtube.com/watch?v=wD9Cs7vRWbQ

Posters

The posters presented at the meeting are listed below. For posters that were available for posting, links to these posters on the NWCC website are included. Some posters contain proprietary or preliminary information and are not available for distribution.

Estimating Impacts to Birds and Bats

A flexible modeling approach to 'road and pad' correction factors for bats in post-construction monitoring projects
Paul A. Rabie, Western EcoSystems Technology, Inc.

An assessment of direct and indirect impacts to waterfowl in an Important Bird Area from wind turbine operation
Nicole Kopysh, Stantec

Assessing direct mortality to avifauna from wind energy facilities in the Dakotas
Brianna J. Graff, South Dakota State University

Avian and bat mortality at two wind energy facilities on the Gulf Coast of Texas
Elizabeth M. Baumgartner, Western EcoSystems Technology, Inc.

Resource Equivalency Analysis: A tool to ensure avian impacts are mitigated?
Brad Norton, ICF International

Assessing Risk to Birds and Bats

Airspace use by night migrating landbirds in relation to the southwestern shore of Lake Erie, OH
Michael J. Wellik, U.S. Geological Survey

Habitat Conservation Plans in Hawaii: history and implications
Alicia Oller, Tetra Tech, Inc.

Prioritization of avian species potentially impacted by wind energy development
Julie Beston, U.S. Geological Survey

Radar monitoring of the federally-listed Marbled Murrelet in northern California: Implications for wind energy development in coastal areas of the Pacific Northwest
Peter M. Sanzenbacher, ABR, Inc. – Environmental Research and Services

The effects of chronic moderate noise on animal behavior and distribution
Jim Cummings, Acoustic Ecology Institute

The value of cultivation as wildlife habitat - congregations of Swainson's Hawks (*Buteo swainsoni*) in southern Alberta
Kent W. Russell, Stantec

Utilizing multi-spectral signatures to identify potentially suitable habitat for sensitive species across regional landscape
Jon Schubbe, HDR Engineering

WREN – a new international collaborative under International Energy Agency Wind
Karin Sinclair, National Renewable Energy Laboratory

WREN Hub – international collaboration to reconcile wind and wildlife conflicts
Andrea Copping, Pacific Northwest National Laboratory

Detection & Deterrent Technologies

Applying radar to wind energy projects: distinguishing fact from fiction
Karen Voltura, DeTect, Inc.

Developing the next generation ultrasonic acoustic deterrent
Michael Schirmacher, Bat Conservation International

Wildlife deterrent using high brightness light sources
Donald Ronning, Lite Enterprises

A tool to visualize sample space and estimate volume of altitude bands sampled by avian radar
Tim Bowden, U.S. Fish and Wildlife Service

Bats & Wind Energy

Understanding meteorological data and variation in bat activity; evaluating thresholds for bat protection and implications for wind energy facilities
Tim Bowden, U.S. Fish and Wildlife Service

Bats and wind energy in Mongolia
Katy Reagan, Sunbird Biological Consultants

Bats of wind farm La Rumorosa, Baja California, Mexico: management advices for their conservation
Minerva A. Uribe-Rivera, Universidad Autónoma de Baja California

Impacts of a single-turbine wind facility on bat activity and fatality in northeastern Iowa
Jerry Roppe, Iberdrola Renewables

Stable isotope and genetic tools for investigating the impacts of wind-turbine mortality on Lasiurine tree bats
David M. Nelson, University of Maryland Center for Environmental Science

Impacts to Mexican free-tailed bats from wind energy development in the western U.S.
Joel Thompson, Western EcoSystems Technology, Inc.

Evidence that bats utilize wind turbines as a foraging resource
Victoria Bennett, Texas Christian University

Bat activity in the Great Lakes region and potential implications for wind energy development
Kevin Heist, University of Minnesota

Applicability of Indiana bat Habitat Conservation Plan avoidance, minimization, and mitigation measures for the Northern long-eared bat
Courtney Dohoney, Ecology and Environment, Inc.

Endangered species challenges ahead: solutions for clearing the Incidental Take Permit hurdle
Quintana Baker, Western EcoSystems Technology, Inc.

Fitting a square peg in a round hole - applying evidence of absence software to Habitat Conservation Plan monitoring for federally listed bat species
Cara W. Meinke, Western EcoSystems Technology, Inc.

Proposed federal listing of the northern long-eared bat (*Myotis septentrionalis*) and implications for the wind energy industry
Susan Hurley, Tetra Tech, Inc.

Understanding the proposed (or recent) listing of Northern long-eared bats
Jeff Gruver, Western EcoSystems Technology, Inc.

The effectiveness of raising cut-in speeds for reducing bat mortality at the Fowler Ridge Wind Farm, Benton County, Indiana
Rhett Good, Western EcoSystems Technology, Inc.

Operational mitigation reduces bat fatalities at the Sheffield Wind Facility, Vermont
Colleen Martin, Texas Tech University

Experimental test of a model based curtailment algorithm
Fränzi Korner-Nievergelt, oikostat GmbH

Offshore Wind Energy: Siting & Assessment

Bats offshore: where, why, and when?
Steve Pelletier, Stantec

Tracking bats offshore in the Gulf of Maine using nanotags
Sarah Boucher, Stantec Consulting Services Inc.

Benthic and fish monitoring at a UK Offshore Wind Farm
Chris J. Pendlebury, Natural Power

Bird and marine mammal monitoring at a UK offshore wind farm
Chris J. Pendlebury, Natural Power

Long term studies on biogenic reefs and implications for offshore developments
Chris J. Pendlebury, Natural Power

Use of PVA to assess the potential for long term impacts from piling noise on marine mammal populations
Nancy McLean, Natural Power

Ecological baseline studies on the Mid-Atlantic outer continental shelf
Kate Williams, Biodiversity Research Institute

The impacts of offshore wind development on birds: pre-construction survey methods and lessons learned from offshore wind pilot projects in the Northeastern U.S.
Aaron Svedlow, Tetra Tech, Inc.

Prairie Grouse & Wind Energy

No fowl, no harm: determining project impacts and the appropriate conservation response for Lesser Prairie-Chickens
Karen Tyrell, Western EcoSystems Technology, Inc.

The Lesser Prairie-Chicken Range-Wide Plan, a faster but more expensive option than an Incidental Take Permit?
Karl Kosciuch, Western EcoSystems Technology, Inc.

Lesser Prairie-Chicken listing and Rangewide Conservation Plan: moving projects forward
Carron A. Meaney, Walsh/Ecology & Environment

Relationships between ranch management, wind energy development, and Greater Prairie-Chicken populations at the Elk River Wind Farm, Butler County, Kansas
Greg D. Johnson, Western EcoSystems Technology, Inc.

Raptors (including Eagles) & Wind Energy

Alta East eagle take permit environmental assessment, start to ….finish
Deron Lawrence, CH2M HILL

Cumulative effects analysis considerations for eagle take permits and NEPA
Michael Morgante, Ecology and Environment, Inc.

Modeling with uncertain science: estimating mitigation credits from abating lead poisoning in Golden Eagles
Taber D. Allison, American Wind Wildlife Institute

Patterns of raptor activity and collision mortality at wind projects in New England
Jessica Costa, Stantec Consulting Services Inc.

Eagle fatality monitoring at wind facilities using operations staff: potentially a viable and cost-effective detection method
Eric Hallingstad, Western EcoSystems Technology, Inc.

Golden Eagle home range, life history, and geographic range information obtained using GPS-GSM cellular telemetry: the potential to develop more effective eagle conservation planning and mitigation strategies
Thomas J. Koronkiewicz, SWCA Environmental Specialist

Overlap between wind energy resources and summer ranges of non-breeding Golden Eagles migrating north from the Southwestern United States
Robert K. Murphy, U.S. Fish and Wildlife Service, Southwest Region

Predicting high likelihood Golden Eagle nest habitat and developing a long term monitoring protocol in disturbance areas
Martin D. Piorkowski, Arizona Game and Fish Department

The effect of wind energy on the Golden Eagle in Spain and a review from Europe
Alvaro Camina, ACRENASL

Additional Resources

The following can be found on the NWCC's Wind Wildlife Research Meeting IX webpage:

- Final Meeting Program
- Presenter Bios
- Presentation and Poster Abstracts
- Powerpoint Presentations (pdf)
- Posters (pdf)

To learn more about NWCC, please visit: www.nationalwind.org.

To learn more about AWWI, please visit: www.awwi.org.