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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 for some species that 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. Because of concentrated investment in detection and deterrent technologies, presentations documented progress being made to minimize impacts in a meaningful way.

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Ordering Information

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

Disclaimer

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Abbreviations

Above-ground level (AGL)
Advanced conservation practices (ACPs)
American Wind Energy Association (AWEA)
American Wind Wildlife Institute (AWWI)
Bald and Golden Eagle Protection Act (BGEPA)
Bats & Wind Energy Collaborative (BWEC)
Bird Conservation Region (BCR)
Breeding Bird Survey (BBS)
Bureau of Land Management (BLM)
Bureau of Ocean Energy Management (BOEM,
    formerly Bureau of Ocean Energy Management,
    Regulation and Enforcement, or BOEMRE, and
    previously Minerals Management Service, or
    MMS)
California Current System (CCS)
Dynamic Brownian Bridge Movement Models
    (dBBMM)
Eagle Conservation Plan (ECP) and ECP Guidance
    (ECPG)
Electric Power Research Institute (EPRI)
Endangered Species Act (ESA)
Federal Aviation Administration (FAA)
Geographic Information Systems (GIS)
Gigawatt (GW)
Global positioning system (GPS)
Global system for mobile communications (GSM)
Incidental take permit (ITP)
Infrared (IR), Mid-wavelength IR (MWIR), Near IR
    (NIR)
International Energy Agency (IEA)
Low wind-speed curtailment (LWSC)
Megawatt (MW)
Migratory Bird Treaty Act (MBTA)

National Environmental Protection Act (NEPA)
National Oceanic and Atmospheric Administration
    (NOAA)
National Wind Coordinating Collaborative (NWCC)
Next generation radar (NEXRAD)
Non-governmental organization (NGO)
National Renewable Energy Laboratory (NREL)
Offshore wind farms (OWFs)
Pennsylvania Game Commission (PGC)
Playa Lakes Joint Venture (PLJV)
Point Count Surveys (PCS)
Population Collision Vulnerability (PCV)
Population Displacement Vulnerability (PDV)
Production tax credit (PTC)
Resource selection function (RSF)
Rotor-swept zone (RSZ) or area (RSA)
Single Nucleotide Polymorphisms (SNPs)
Supervisory control and data acquisition (SCADA)
    system
The Nature Conservancy (TNC)
Turbine-Integrated Mortality Reduction (TIMR)
United States Department of Agriculture (USDA)
United States Department of Energy (DOE)
United States Department of Fish and Wildlife
    Service (FWS or the Service)
United States Geological Survey (USGS)
Western Golden Eagle Team (WGET)
White nose syndrome (WNS)
Wind energy area (WEA)
Wind resource area (WRA)
[IEA's] Working Together to Resolve Environmental
    Effects of Wind Energy (WREN)

Welcome and Opening Remarks

Welcome

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

Welcome to a record-breaking number of attendees at this 11th Biannual Wind Wildlife Research Meeting. This is an excellent opportunity to engage with each other as stakeholders for the timely and responsible development of wind energy and the protection of wildlife.

This is an open forum to share the latest research results, and to engage in dialogue. We received a record number of abstracts. All abstracts were peer-reviewed. There were many more abstracts than could be incorporated into the program and many of these are presented in our poster sessions. These sessions are a significant part of the research meeting and an excellent way to share results and discuss projects with the investigators. We have included substantial time in the program for poster viewing, and I encourage all participants to spend time in these sessions, as there is a lot of important work being presented there. We will make as many of the posters and presentations as possible available online, with our proceedings to be published online in early 2017.

Opening Remarks: Retrospective and Looking Ahead

Abby Arnold, Executive Director,
American Wind Wildlife Institute

Our quest for knowledge could not be more important. Finding ways to produce electricity to light our homes and run our electronics from wind – a clean, emission and water-free technology that in the United States provides at least 88,000 jobs and produces 75 GW of electricity while mitigating climate change – could not be more urgent. Two years ago for the first time at these meetings, we heard from David Cottingham of the U.S. Fish & Wildlife Service about how the impacts of climate change on wildlife are the first challenge of our community to address. We also heard the results of a USFWS and National Audubon study modeling the projected effects of our changing climate on North American birds are imperiling more than 300 species. Each of the past three years – 2014, 2015, and 2016 – has been the warmest year in the 137 years of record-keeping. 2015 was the first year when the temperature anomaly exceeded 1 degree Celsius.

As we try to contemplate what a new U.S. administration will bring – whether we are regulators, scientists, wind developers, consultants, researchers, or environmental advocates, from a wind-rich remote region or urban center – what binds us is our dedication to improve knowledge and develop solutions for wind and wildlife.

We have learned a lot in 23 years, yet the question of how to predict and reduce the risk to wildlife from wind energy development remains before us. In a world where change is occurring rapidly and decisions cannot be deferred until we know all that we would like to know, we need to think hard about which uncertainties to focus on, and what we are willing to accept. We will have choices about how to prioritize our research.

At the International workshop that preceded this meeting, we heard that progress towards understanding and addressing wind-wildlife impacts has been made in the U.S., Canada and Europe relative to many parts of the world. At the same time, we can expect rapid increases in wind development to occur in other, less-developed parts of the world. Our collaboration must be not just national but global.

I want to thank the Department of Energy (DOE) and its National Renewable Energy Laboratory (NREL) for making this work and these meetings possible over these 23 years, including supporting publication of these proceedings. The American Wind Wildlife Institute now has 27 wind industry partners and friends, including turbine manufacturers, companies that site, develop, operate and purchase power; nine national conservation organizations; and the Association of Fish & Wildlife Agencies (AFWA). Without the support of every one of these partners and friends, this work would not be possible. We thank our meeting sponsors for keeping the cost of participating in this meeting affordable. Finally, I want to thank all the Federal agencies – Fish & Wildlife Service, U.S. Geological Survey, the Bureaus of Ocean Energy Management and Land Management – and the state agencies and AFWA for your involvement and support of this our collective efforts to understand these issues. Along with the consulting community and academics, each person at this meeting represents a community whose cooperation and collaboration is valued.

We may differ on the importance of wind relative to other renewable energy resources; we may have differing views of how much data and analysis is enough; but all of us are committed to improving our understanding and developing solutions to address the challenges we face as a community. AWWI is committed to improving our knowledge about the impacts to wildlife from wind and solutions that will help us avoid, minimize and mitigate those impacts. We will continue to raise funds to provide a safe forum for us to learn from one another, because we believe that only through improved understanding can we find durable solutions.

Framework for Policy Questions Going Forward

United States Fish and Wildlife Service

Noah Matson, U.S. Fish & Wildlife Service

Noah Matson is Senior Advisor to the Director of the U.S. Fish & Wildlife Service (USFWS). He advises, coordinates and leads policy activities regarding renewable energy, water, migratory birds, and co-led the revision process for the USFWS' eagle incidental take regulations.

I want to begin my remarks by talking about a species that occurs far away from turbine blades: the polar bear. Polar bears depend completely on sea ice for hunting and other needs. This year marks another record low for incidence of sea ice in the Arctic, marking a long trend of decline. In just a few years, the Arctic is expected to be ice-free in the summer. We've all heard tales of emaciated polar bears swimming hundreds of miles from land and sea ice, emaciated and drowning.

There is a reason the polar bear is the icon of climate change. How do we conserve polar bears when the very conditions upon which they evolved and depend are disappearing from the planet? What is our adaptation strategy? There are many other species in the same boat, where the only adaptation, the only conservation strategy is to limit greenhouse gas emissions, period.

This is a hard thing for wildlife conservationists. We're used to radio-collaring animals and moving dirt, not participating in energy or air pollution policy. How do we trade the life of a songbird or a bat for the existence of the polar bear? How do we save wildlife while saving the planet? That's the most critical question.

The research priorities outlined by this conference and by AWWI are tactical, and focus on the current speed bumps in our journey toward answering that bigger question. But we also need a bigger frame. We need new principles for what conservation is. We need new ways to define our goals; we need new scientific and analytical tools that make sense of the risks and trade-offs. We need a way to see the forest for the trees. We need to move beyond project-by-project decisions.

I don't think many people truly understand the extent of the changes to come. Already the Forest Service is buckling under a prolonged and intense fire season that threatens to bankrupt that agency. Already, huge storms have laid waste to coastal communities. Already, an overheated climate has erased snowpack in the West. California is still reeling from five years of the worst drought in millennia. That is what we are experiencing with only a 1-degree increase

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in global average temperatures. The international community is trying to achieve a 2-degree limit to the increases, and who knows if we will get there.

All of these changes are dramatically affecting fish and wildlife and plants. There is no doubt that the world is going to look very different in a few decades. The question is, will it be recognizable?

The answer is not wanton development of renewable energy at all costs with no regard for impacts on wildlife. Neither is the answer intractable permitting by Federal agencies. The research all of you are involved with is essential to charting the path forward to save wildlife while saving the planet. I look forward to this discussion. Thank you.

United States Department of Energy

Jocelyn Brown-Saracino, U.S. Department of Energy

Jocelyn Brown-Saracino manages the environmental resource portfolio for the Department of Energy's Wind and Water Power Technologies Office. She supervises projects aimed at measuring, mitigating and sharing information on environmental impacts of wind and hydropower technologies.

I want to begin with what has been accomplished in this area since the last research meeting in 2014, and about opportunities going forward. That year the Department of Energy (DOE) previewed its Wind Energy Vision report, which established a goal and a roadmap for wind resources to supply 20% of our electricity by 2030, and 35% by 2050. The report projected significant reductions in water consumption, greenhouse gas emissions, and air pollution if we realized that scenario. We have made a lot of progress over these past two years:

- Last year, 5.5% of the nation's electricity came from wind. This rivaled the contribution from hydro-power, which is currently the largest source of renewable energy in the U.S.

- 8.6 GW of wind was added to the grid in 2015, making wind the largest new source of energy: 41% of all new electricity capacity added in 2015.

- The wind energy industry employed 90,000 people in the United States in 2015, and according to the Bureau of Labor Statistics, wind turbine technician is the nation's fastest growing profession.

- In 2015, wind energy reduced electricity sector CO_2 emissions by more than 128 million metric tons, equivalent to $5 billion in avoided climate damages. The savings from reductions in air pollution totaled $8.7 billion and avoided 1,100 premature human deaths. On a per kilowatt basis, these environmental benefits alone are worth triple the cost of the Production Tax Credit (PTC).

- This year, this nation's first offshore wind energy facility went into operation.

The roadmap for realizing DOE's Wind Vision seeks to deploy wind in such a way that it co-exists with wildlife. We have made a lot of progress in that regard.   In regard to offshore wind, the DOE has recently completed the largest ever survey of birds, marine mammals and sea-turtles in the mid-Atlantic – a project funded through the Biodiversity Research Institute. We also completed the most extensive study to date of when and where we find bats in the offshore space. In regard to land-based wind, DOE has committed, subject to our annual budget, supporting the NWCC and the Bats & Wind Energy Collaborative (BWEC), and of the International Energy Agency's WREN (Working Together to Resolve Environmental Effects of Wind Energy) Initiative.

Most recently, we have awarded funding to projects submitted in response to a solicitation to improve and validate technologies to minimize wind energy impacts on eagles. There were two projects under each of three topic areas.

1) Improve our understanding of eagle physiology to better design deterrent devices:

- University of Minnesota, in partnership with Boys Town National Research Hospital, will map the hearing capabilities of Bald and Golden eagles and red-tailed hawks.

- Purdue University, in partnership with USGS, will map the visual and auditory physiology of Golden eagles, and also perform behavioral trials to identify optimal deterrent stimuli.

2) Further developing and testing mid-technology readiness level devices to expand the number of technology solutions at our disposal:

- Laufer Wind Group in partnership with NREL, Auburn University and the Southeastern Raptor Center, will develop and demonstrate a system combining off-the-shelf radar with the SCADA system to detect eagles and shut down turbines when eagles are at risk.

- Oregon State University, in partnership with USGS and NREL, will develop integrated system that uses a camera to detect eagles, a simple visual deterrent system, and a blade-mounted collision detection system.

3) Provide transparent validation for commercial-ready technologies:

- AWWI in partnership with Renewable Energy Systems (RES), WEST and others will validate RES' Identiflight system, testing its effectiveness compared to biomonitors at detecting identifying and triggering turbine shut-down to reduce risk to eagles.

- AWWI in partnership with Liquen Consulting, HT Harvey and others, will validate the DT Bird system, looking at how well it detects and deters eagles.

We have done a lot collectively over the past couple of years, and I believe strongly that we have a lot of good work to look forward to over the next couple of years.

A Conservation Organization Perspective

Joy Page, Defenders of Wildlife

Joy Page is Senior Policy Advisor for the Defenders of Wildlife's Renewable Energy and Wildlife Program, which focuses on facilitating wildlife coexistence with wind and solar energy. She works with federal agencies and developers on the full range of mitigation strategies. She brings both scientific and legal expertise to this work.

This is one of the most important meetings I attend. Defenders of Wildlife is an organization that works to preserve wildlife habitat as well as biodiversity. From Defenders' perspective, as Noah so eloquently put it, climate change really poses the single greatest challenge to wildlife. We have to caution ourselves against saying "future impacts," because the impacts are real and already happening NOW. And habitat degradation is also happening across the landscape, with wind energy development being just one factor. As a conservation organization, it can be challenging to tackle those climate change threats to wildlife at the same time reconciling those short-term impacts to wildlife from wind energy. Defenders of Wildlife has been a firm believer from the beginning that we can and must do both – protect wildlife and pursue renewables – and quickly.

The threats remain constant. We are big supporters of distributed generation, where possible, but realize that wind energy build-out and other renewables are going to be critical to meeting the carbon reduction levels needed to affect climate change. Our president was on the advisory plan of DOE's Wind Vision. We must be strategic, focused and collaborative to accomplish our goals. Now more than ever we need to work together.

A State Wildlife Agency Perspective

Scott Smith, Wyoming Game & Fish Department

Scott Smith is Deputy Director of External Operations for the Wyoming Game and Fish Department, and has served as a wildlife biologist for 33 years.

Wyoming is an energy state: not long ago we were the leading exporter of BTUs in the nation. But we also rank first in high-class wind resources, with Class 6 & 7 sites in southeast corner of the state. Given those resources, the largest onshore wind energy project now in development in the nation is the Chokecherry-Sierra Madre project. When completed, it will comprise 1,000 turbines, with an estimated capacity of 3,000 MW.

Wyoming is also nationally and internationally known for its abundant and diverse wildlife resources, with over 800 species of wildlife including pronghorn antelope, mule deer, elk, moose. The state supports over half of all the Greater sage grouse in North America. Eagles are abundant as well; a 2011 study documented over 1,400 nesting pairs of Golden Eagles. We are also a headwater state for four major river basins. Over 28,000 miles of streams support 77 species of fish. The challenge facing our state is to find that balance between renewable energy production and wildlife protection. I am glad to hear that there will be more funding to support research on eagle detection and deterrent technologies.

A Wind Industry Perspective

Sam Enfield, Windline Development

Sam Enfield is a managing member of Windline, which provides wind energy development services with particular concentration on regulatory and environmental issues. He has been involved in the wind business for over 20 years. He serves on the Board of Directors for the American Wind Energy Association (AWEA) and co-chair's AWEA's Siting Committee.

I have been coming to these meetings since they started, and I always have found them to be extremely productive. The opportunity to get the technical people from the wildlife agencies, the NGOs, the industry and consultants. In my experience everyone tends to feel better walking out of this meeting than we did walking in, and that is a very good thing.

QUESTIONS for Opening Panelists

Q: *What are the concerns that are coming up after this year's elections?*

A [Sam]: Turbine costs are coming down and efficiency going up, which we need, because we face prospect of competing with natural gas which has multiple permanent incentives, while we expect to be losing the Production Tax Credit and the Clean Power Plan that we had been counting on. Transmission has been built, but it is filling up. It takes a long time to plan and build transmission. This forces us to move closer to load centers – into closer proximity to people, which poses a whole other set of complications.

A [Jocelyn]: The Wind Energy Technology office is very committed to working on wind-wildlife issues. Eagles, bats, and sage grouse are the three primary land-based wildlife concerns. Also offshore species. Aggregate information are being collected all over the world.

There may be a freeze across federal agencies, but it is not yet clear. We are under a short-term continuing resolution, probably through March – at which point either there will be a new appropriations bill passed or we will continue through the regular budget cycle.

A [Joy]: In uncertain times, collaborative efforts are more important than ever. As a result of aggressive renewable portfolio standard mandates – utilities see the value of this work in advancing wind acceleration and deployment. Also the broader manufacturing community are increasingly more supportive of addressing climate change by powering their facilities through clean energy generation.

A [Sam]: The Federal financial incentive (production tax credit, or PTC) has been important, but state renewable portfolio standards are key in driving utility purchases of wind energy.

Q: *What is the role of the National Labs?*

A [Jocelyn]: DOE has network of 17 national labs, our "brain trust" – modeling analyses, including economic and environmental. PN lab taking the lead in the offshore wind space. NREL leads land-based wind work – NWCC, WREN (task under International Energy Agency – nations committed to working together to resolve wind and wildlife issues), BWEC

Q: *What does the Service see as its wind-related research priorities?*

A [Noah]: Again, the research priorities outlined by this conference are all important. We need a better understanding of the behavior, interaction, and impacts of wind energy facilities on protected species, like eagles and endangered bats. We need more research on methods to deter species and avoid and reduce impacts. But we also need new analytical tools to better understand the national and global context of individual permitting decisions. Permitting a renewable energy facility, which has global environmental benefits that will help species, needs to have an approach that acknowledges this benefit, while balancing more local, and short term impacts. Finally, the Service is severely short-staffed and unlikely to be able to dramatically increase its workforce. Any research that results in better analytical tools to base permitting decisions, or on best management practices that can be incorporated into permitting easily will reduce our workload, reduce permitting time, and increase the conservation benefits of our decisions.

A [Scott]: Research plays huge role in how we address impacts. Two monitoring research projects at Chokecherry-Sierra Madre project. Looking at mule deer productivity, and sage grouse nesting success at the front end of this project. BACI study design so that we can scientifically understand.

The Recovering American Wildlife Act (HR6550) would dedicate $1.3 billion from (offshore) energy to support research for non-game species. If this bill survives and moves forward in any form, would be a huge boost to the states to learn about species that we have no information or very little on. There are 29 sponsors on this bill, so we are optimistic.

Abby: The states need more resources to fund non-game research. States are leading this initiative – research and protection of non-game species. The Association of Fish & Wildlife Agencies (AFWA) helped to spearhead this effort.

Q: *If USFWS is down 1,000 people and faced with a hiring freeze, why do you keep coming out with new complicated permitting programs? Do you expect the Service will need increased contracts with universities, nonprofits, and consulting groups to execute the research and enforcement of regulations related to wind energy?*

A [Noah]: There are certain functions we can't contract out, like law enforcement, but we rely on academic and other partners to conduct research. The U.S. Geological Survey does great scientific work, and we share our resource priorities. (See Mona Khalil at USGS.)

I disagree with the premise of the question, however. The policy and regulatory reform agenda of this administration has been to reduce the burden on the regulated community and workload burden on the government, while providing a greater conservation and environmental benefit. The eagle incidental take rule is a prime example of this. By completing a programmatic environmental impact statement on the new rule, we will be able to "tier" individual permits to this document, reducing time and workload necessary to process permits – permits that are now valid for up to 30 years.

Q: *It is a major milestone to have our first offshore wind farm come on line. However, the progress has been very slow. What do you see as the likely path forward, and where you think we will be in the Atlantic and Pacific in the coming years?*

A [Jocelyn]: DOE works closely with the Bureau of Ocean Energy Management, which is responsible for the approval of a construction and operations plan submitted by developers for wind facilities on the Outer Continental Shelf. The Real-time Opportunity for Development Environmental Observations (RODEO) is a joint strategy between DOE, the Department of the Interior, and BOEM to take real-time measurements of the construction and operation of the first facilities to be built to allow for more accurate assessments of the actual environmental effects.

Q: *What is the potential for offshore development in the Great Lakes? Is this possible to develop?*

A [Jocelyn]: There is one demonstration project in the Great Lakes. The fresh water environment poses different questions, and we are interested in seeing it developed.

A [Noah]: Offshore is where international collaboration is so important. The US is still new to this and other countries have done a lot more. For example, we now know that bats fly 60 miles offshore – no one had any idea about this before.

Q: *With regard to offshore development, where does FWS jurisdiction stop and NOAA start?*

A [Noah]: The FWS manages birds under the MBTA, threatened and endangered bats, and certain marine mammals (sea otters, walrus, polar bear, and manatees). NOAA manages marine

fisheries, threatened and endangered marine species, and other marine mammals (seals, sea lions, and cetaceans).

Other responses related to offshore wind energy development:

A [Jocelyn]: We have a long history of doing construction offshore, even though not wind. We can combine what we've learned from land-based wind energy to think about impacts from the waterline up, and look to other types of offshore construction experience to consider impacts from the waterline down.

A [Joy]: Defenders has not yet been engaged in offshore wind, but we are starting to look at that in California. A lot of same concepts – such as offshore sanctuaries – apply. Post-construction monitoring is the biggest issue – how do we evaluate the impacts and validate our predictions about likely impacts?

A [Sam]: From the industry's perspective, the cost of offshore wind is the biggest challenge.

Q: *The levelized cost of energy drives what gets built, and where. From a development perspective, where does the wildlife question fit in to "cost is king"?*

A [Sam]: Purchase and installation of equipment, which are fixed costs, represent the majority of the cost of wind energy. Wind companies compete hard with each other on price, which leaves little margin for error. If production suffers or operating costs go up for mitigation costs you hadn't anticipated, that makes it harder to finance future projects. More risk raises the prices. Minimizing risk and uncertainties is key.

DOE has been investing funds for eagle and bat research. FWS, USGS, etc. don't have funds to support this research in a significant way.

Q: *Where do you see wind energy falling in priority and importance as new energies like nuclear fusion continue to develop?*

A [Jocelyn]: The DOE has a long history of working on these issues (25 years), and this has ramped up in recent years. We are programmatically committed, but funding depends on the Congressional budget. We do have a request for information (RFI) out to the wildlife community to look at smart curtailment for bats and validating compensatory mitigation for eagles.

A [Joy]: Conservation organizations will continue to focus on impacts to bats. We need population information and solutions for impacts to migratory tree-roosting bats from wind energy, and we need to find solutions for White Nose Syndrome, which is the greatest threat to cave roosting species.

Q: *With potentially less funding for research available, will there be greater acceptance of research investments serving as compensatory mitigation?*

A [Noah]: FWS mitigation policy allows for the consideration of research as mitigation under limited circumstances. For example, for a threat like White Nose Syndrome research might be appropriate since there is no currently known solution to reducing this disease's impacts It is tricky to quantify a developer's contribution to a research and come up with the equation for compensatory mitigation.

Q: Looking to the future –is there a way to rethink our approaches that research would help to make possible?

- We've had a lot of comments about projects that pose a "low risk to eagles." Having such a designation would allow FWS to prioritize our limited resources, and would benefit industry as well. The challenge is figuring out how we define "low risk", what research inputs are needed, and how we would structure low risk permits.

- Defenders of Wildlife wants issuance of permits, definition of "low-risk". Dollars paid into low risk permits could pay for research on high priority issues.

- How do we move from monitoring every project to having more certainty about certain interactions or have enough confidence in predictive ability so that we can get away from monitoring every single project ("risk retirement")?

- From the state wildlife management agency perspective, while there's a great need for data, lack of sharing pre-build baseline data results in a lot of redundant pre-construction studies. If we could share that data, we could learn more while better investing our research dollars.

- Industry is painfully aware that vast majority of monitoring costs produce very little conservation benefits. I've been wondering if the fact that we're operating under a permit places pressure on agency to require more monitoring to validate assumptions than the underlying risk really requires.

- Agreed: We should be able to validate assumptions across the industry, not on a project by project basis. Other industries have proven technology solutions – for example, fishing nets fitted with a device to prevent turtle take. In two years, we'd like to be able to see more technologies that have been validated so that the FWS can just say: you've got that technology, you're good to go, no monitoring requirements.

Additional questions not addressed during the Session Q&A

Q [for Noah]: *Is the 4(d) rule for NLEP expected to continue into the foreseeable future?*

A [Noah]: The FWS expects the 4(d) rule for the Northern Long-eared Bat to remain in effect. However, if the species continues its dramatic decline due to white-nose syndrome, it may become listed as endangered, and the 4(d) rule would no longer apply.

Q [for *Scott*]: – *What species of Myotis bats exist in Wyoming? What is the status of these species' populations, and what do you envision recommending for operational mitigation practices for the Chokecherry-Sierra Madre project in terms of curtailment (minimum cut-in wind speeds)?*

A: There are eight species of *myotis* in Wyoming, but not all would occur in the project area for the Chokecherry-Sierra Madre wind farm. There is potential for little brown, fringed, long-eared, long-legged, Western small-footed, and Yuma to occur in the project area. California and northern long-eared are not expected to occur in the project area. For those species with the potential to occur we consider little brown, long-eared, long-legged, and Western small-footed to be common, fringed to be uncommon, and Yuma to be very rare.

Myotis don't tend to be the big group of species impacted by wind energy development in Wyoming, although they are certainly among those killed, and, with other threats (White-nose Syndrome among others), wind energy mortalities are likely to become more of a cumulative impact. The forest bats are those most heavily impacted, which, in Wyoming include: hoary and silver-haired bats (common in Wyoming), and Eastern red bat (rare).

The Department commonly recommends curtailing nightly operation of turbines during high-risk periods, including migration times for bats and times of low wind speed (less than 13 mph). Other standard BMPs recommended for wind energy development include:

- Ensuring that the use of experimental technologies, such as bat deterrents and radar, are evaluated to improve understanding of application.

- If habitat evaluation and pre-construction monitoring indicate that potential risks to bats are higher than initially expected, then consider alternatives such as revising project design.

- Where possible, locate new wind energy facilities on lands that are already developed, cultivated, or disturbed. Place linear facilities such as transmission lines and access roads in or adjacent to existing disturbed corridors to minimize habitat loss or fragmentation.

- Avoid placement of infrastructure, including roads and turbines, within a quarter mile of known bat roosts.

- When siting wind turbines within two miles of areas that are potentially high risk for bats, consider increasing survey effort by increasing survey length and intensity to improve the evaluation process and siting or turbines.

Raptors and Wind Energy: Lessons Learned from Altamont, Estimating Origins and Fatalities

Moderator: Kimberly Peters, DNV GL Energy

U.S. Raptor Mortality Estimates from Wind Energy for the U.S.

Presenter: Wallace Erickson, Western EcoSystems Technology (WEST), Inc.

Authors: Kimberly Bay, Shay Howlin, Wallace Erickson *(Western EcoSystems Technology, Inc.)*

PROBLEM / RESEARCH NEED

The effect of wind energy on raptors, especially eagles, is the focus of extensive management and research efforts. A 2014 analysis of small passerine mortality estimates was the first study to provide both continent-wide and biome-specific fatality rates for passerine species, with overall passerine impacts found to be very low: <0.01% of populations. As with the small passerine study, this analysis sought to determine effects for raptor species based on data compiled from a large number of studies across the United States.

Objectives
Our objectives for this analysis were to:
1. Develop accurate estimates of raptor mortality by species.
2. Compare mortality to population size estimates.

APPROACH

As with the 2014 small passerine analysis, we looked at a much larger dataset than had been previously examined. Criteria for inclusion in our analysis included: use of standardized, current search methods (including bias correction); at least three-quarters of a year study periods; and reasonable (<30-day) search intervals. After screening for these criteria, we compiled data from over 146 comparable studies on avian fatality at over 85 wind energy facilities. Together, these facilities represented about 15% of all wind energy currently in operation in the United States. The original plan was to use biomes as we did for small passerines, but we ran into issues with small samples and small species composition size, so we were limited to splitting the analysis into two regions, the Western U.S. (west of the Mississippi) and the Eastern U.S.

The studies used a variety of estimators, and we had to adjust for a variety of biases in looking at the data. How searcher efficiency and carcass removal assumptions are incorporated can lead to biased estimates, so we developed estimator bias corrections based on extensive simulations under different conditions. We then evaluated the characteristics of each study and applied bias correction, using both a conservative approach (Method A) and a less conservative approach (Method B) to making those adjustments. We also applied corrections for plot size bias. For partial-year studies we assumed that mortality was proportional to what we would see with year-round data. (We did consider seasonality for raptors, but found this to be much less of a factor than what we see for nocturnal migrants.)

Because fatality detection rates differ for small vs. large raptors, we separated those data and adjusted for the differential in detection bias. For all studies we made another conservative correction, substituting non-zero values for zero. We did *not* adjust for background mortality or use of surrogate carcasses in persistence trials, although there is some evidence that surrogates such as game birds and rock birds are removed faster than large raptors.

FINDINGS

Raw Guild Composition
Passerines were by far the most common species found. Owls comprised 1% of the carcass records, vultures 1.2%, and all other raptors 7.8%. However, the raw composition numbers likely overestimate the actual fatality composition for raptors because raptors are more detectable than other smaller bird groups. Note that we separated out owls and vultures from all other raptors, because many studies that were included only reported standardized estimates for raptors after excluding owls and vultures.

Diurnal raptor species composition
For all studies combined, we analyzed fatalities of 15 species of raptors. Two diurnal raptor species comprised 75% of the raptor mortality:
- Red-tailed hawks were the most common raptor species found (203 fatalities)
- American kestrels (179) – mostly in the West

We adjusted the species composition based on detection probability bias, so for example, the red-tailed hawk (ie a large raptor) made up 40% of the 508 diurnal raptor fatalities recorded in these studies, and the American kestrel 35% (small raptor). Once adjusted for detection probability based on the relative sizes of these birds, red-tailed hawks accounted for 31% of adjusted diurnal raptor mortality, and kestrels 48%. Sharp-shinned hawk (3% of total raptors), golden eagle (2%), Swainson's hawk (2%), northern harrier (2%), Cooper's hawk (1%), rough-legged hawk (1%), and ferruginous hawk (<1%) are the next most common. There were no bald eagles in this dataset, but we know they have been documented at wind energy facilities.

After adjusting the observed fatality rates for sources of bias, we calculated raptor fatalities per megawatt per year for the 38 Eastern and 47 Western U.S. wind facilities (phases are combined), and then multiplied that by the number of MW in each of those two regions to

come up with the continent-wide rate of approximately 0.1 to 0.2 raptor fatalities per megawatt per year (excluding vultures and owls), or about 6,500 to 13,500 diurnal raptor deaths per year (excluded vultures and owls). We estimate approximately 1,000 to 2,000 owl fatalities per year and 900 to 1,850 vultures per year, resulting in an all-inclusive raptor estimate of 10-22,000 total raptors in the U.S., or 0.13 to 0.26 per MW per year.

Overall raptor mortality is higher in the West than in the East, with 90% of raptor mortality occurring in the western U.S. (west of the Mississippi) where 81% of wind energy MW have been installed. Broken out by species, we estimate between 4,000 and 8,000 American kestrel fatalities per year – most in the Western half of the country.

CONCLUSIONS / APPLICATIONS

Compared to U.S. population sizes, less than 0.5% of the breeding population of raptors is directly impacted by wind turbine-related mortality. This is greater than what we found for songbirds. Based on work done by the U.S. Fish & Wildlife Service, about 2-4% of Golden eagle mortality from anthropogenic sources is from wind.

Background mortality, which we did not adjust for, is another challenge to consider. For example, studies in the Altamont suggest some of the burrowing owl mortality may be from background sources.

Our estimates are about half to 20% of previously published mortality estimates, in part because of different methods used, but also because we were looking at a much larger dataset.

Surrogate bias remains a source of potential bias in these results that might be important to consider. We estimated, admittedly based on limited studies, a 40-400% positive bias for larger raptors when using surrogate carcasses, which have both lower detection rates and higher removal rates than do large raptors. One suggestion would be to work with the U.S. FWS to get permission to leave raptors (not eagles) in the field to look at removal rates. We've also had some success getting raptor carcasses from airports, with appropriate permits through the USFWS (suggest contacting the USFWS First) to use in detection and removal trials.

Next Steps
Our next steps would be to try to address the surrogate bias issue, which is likely to be both site and region specific, varying with factors like vegetation, scavenger community and species of trial carcasses used. We may also want to look at background mortality for some species. We will continue to update this analysis based on the increase of MWs across the U.S. and the inclusion of additional studies. Ultimately, given these numbers, we need to be able to quantify the impact of mitigation measures for eagles and other species.

Scientific Insights and Lessons Learned from the 9-year Monitoring Program in the Altamont Pass Wind Resource Area

Presenter: Douglas Leslie, ICF International

Author: Douglas Leslie (*ICF International*)

PROBLEM / RESEARCH NEED

Altamont Pass Wind Resource Area (WRA), located in the rain-shadow of the coastal mountains east of San Francisco Bay, is one of the oldest and until recently largest wind farms in the U.S. Distributed over 37,000 acres (150 square kilometers) of rolling grassland hills and valleys, it has included up to 5,400 wind turbines, which together have a rated capacity of approximately 580 megawatts (MW). In 2004, Smallwood & Thelander published a study showing high annual fatalities of Burrowing owls (>350), American kestrels (> 300), Red-tailed hawks (~300), and Golden eagles (> 100). Despite this evidence, Alameda County renewed conditional use permits in 2004 with no conditions. This resulted in a lawsuit which shut down turbine operations and led to a settlement agreement that established: a 50% avian fatality reduction goal (from a baseline defined by Smallwood and Thelander's 2004 study); a monitoring program to measure that reduction; and a Scientific Review Committee to oversee the monitoring effort.

Objectives
The original intent of this effort was to compare the results this monitoring effort (with the mitigation measures implemented) with the 2004 baseline fatality numbers from Smallwood and Thelander.

Previous estimates of facility-wide fatalities were based on detection probabilities that were not measured, and different "guesses" about what those detection probabilities were led to widely variable estimates and generated considerable controversy and confusion. Facility-wide fatality estimates from the most recent effort were based on detection probabilities that were actually measured, although estimates were produced using data collected from several studies implemented by the monitoring team over several years.

Insights derived from this program with respect to sampling design, statistical rigor, and setting up and implementing a scientifically credible, responsible, and effective scientific oversight process have widespread applicability.

APPROACH

The monitoring program was unique in that it looked at the entire WRA, in which six wind companies were operating turbines over a large variety of topography and turbine types. Over a nine-year period, over 2000 turbines were sampled. During the first five years, about 45% of all turbines were sampled using a long (30- to 51-day) search interval; during the last four years, a smaller but still substantial number of turbines (~26%) were sampled. Avian use sampling was conducted throughout the study, using 47-92 observation points.

Measures to Reduce Fatalities

Three types of measures were implemented to reduce fatalities, including hazardous turbine identification and removal, which had a small effect, and repowering on the part of one wind company, which was not a management action *per se*. The most important fatality reduction measure was a winter shutdown of turbines. This took different forms, ranging from 2-month shutdowns (effectively 19% of the year) to 3.5-month shutdowns (effectively 29% of the year).

The winter months comprise the period of lowest wind energy production and highest raptor use. Observations showed that avian use doubled for Red-tailed hawks during the winter months, and increased by a factor of 1.8 for kestrels and 1.4 for Golden eagles. The rest of this presentation looks at the impact of shutdowns during the last five years (2009-2013), when all repowered turbines were shut down for 3.5 months of the year – a relatively huge treatment.

FINDINGS

Fatality monitoring results reveal a lot of annual variation in the estimates of numbers of birds killed. While there is some evidence for moderate decline during the years when turbine operation was curtailed in the winter, the effect is not nearly what one might have expected for a three-month shut-down. Slopes are negative, but not significantly different from zero. This is true for the larger raptors – Red-tailed hawks and Golden eagles, and even more true for Burrowing owls and kestrels.

Why and so little effect given such a huge treatment? We considered two possibilities:
- **Detection Probability** – variation in detection probability between years could have been substantial, but was not measured.
- **Background Mortality** – we compared carcass detection rates during the shutdown period (November 1 through February 15 each year) and outside the shutdown period (February 16 through September 30 of each year) for the last 5 years of the study when the 3.5 month shutdown was in place.

Carcass placement trials to estimate detection probability were implemented during the first year of the monitoring program, but some members of the Scientific Review Committee did not agree with the approach because non-native species were used in the trials. A 2007 paper described a meta-analysis of searcher efficiency and carcass removal rates across the country and came up with average detection probabilities – the argument being that using these

averages as a standard for different studies would make those studies more comparable. Unfortunately, this does not work. Towards the end of the Altamont study we combined searcher efficiency and carcass removal rates from three different studies that we had done over the course of the nine-year program. We came up with a model to analyze those detection probabilities. The problem is that they were average detection probabilities across the entirety of each study, which meant we had to assume that detection probability was the same over each year of the monitoring program, which it undoubtedly was not. (The last 5 years of the study occurred during the worst drought ever recorded in California; with no rain, grass doesn't grow and carcasses become easier to detect.)

The comparison of carcass detection rates showed that carcass detection rates were significantly lower during the shutdown period for virtually all large bird species not likely to be subject to predation. Conversely, nearly all species for which we had a large enough sample size had carcass detection rates that were significantly higher during the period when the turbines were shut down that during the period when the turbines were operational. Why? We considered that background mortality might be different during the two periods.

From November 2014 through February 2015, we took a closer look at background mortality during the seasonal shutdown period by conducting searches on ridges without turbines and comparing results to searches conducted on ridges with turbines. We used a matched pairs design with area searched kept equal between treatment and control. We located a total of 34 ridges without turbines (all but three of which had previously had turbines on them). We then selected matching turbine ridges based on ridge location, elevation, direction, and habitat, usually a ridge immediately or almost immediately adjacent to the non-turbine ridge. In some cases, we had to select more than one turbine string or a partial turbine string to keep treatment and control search areas equal.

We conducted a total of 338 searches of matched turbine and non-turbine ridges, with an average search interval just under 11 days. A total of 58 valid fatalities (i.e., estimated to have occurred within the search interval) were found, with more fatalities at ridges with turbines than without. The overwhelming majority were small birds subject to predation: 31 at ridges with turbines and 14 at turbines without. Taken together, this suggests that background mortality may be a significant issue.

CONCLUSIONS / APPLICATIONS

In the end, the monitoring program produced a new paradigm for estimating detection probability, implemented several important ancillary studies including estimating the size of the burrowing owl population in the study area, assessing the role of background mortality factors, and shedding light on the relationships between raptor use, fatality rates, turbine size and type, and the effectiveness of shutting down turbines during the winter period when raptor use was highest.
- The effectiveness of repowering may be overestimated for species subject to predation.
- The evidence suggests that curtailment does work for larger predatory birds.

- Circumstantial evidence suggests background mortality may be confounding results. If you eliminate that, you do get a significant decline in burrowing owl fatality rates over the course of the monitoring program.
- Detection probability can confound results. This is particularly important if monitoring lasts more than a few years.

Questions & Discussion

Q: *At many projects, conservation goals are multi-species. These are complex ecosystems, and curtailment that decreases mortality for one species may increase for prey species. Comments?*

Doug: Estimating fatalities at wind farms is extremely difficult! You need to focus your objectives down to get useful information from the research. Management plans need to be species-specific.

Wally: Agreed. Looking at individual species behavior is important. One size does not fit all.

Q: *How did you define a population, and how might that definition have biased your conclusion? Would it have been more appropriate to quantify/compare numbers of species killed relative to local/regional populations vs. overall U.S. populations?*

Wally: We were looking at U.S.-wide populations, and breaking that population into two strata (west vs. east). I believe that the literature includes information regarding populations that suggests one population for many species. Each individual project often does consider effects on local populations, such as looking at nesting, and the Eagle guidance does address impacts to local populations. Site-specific work also important. This study focused on the big picture.

Q: *Is there a funding mechanism available to expand fatality studies to address data gaps (e.g., carcass persistence) – or does this cost fall on project owners? If so, how do we incentivize industry to start addressing some of these gaps?*

Wally: Background mortality represents a large data gap. This is not a new issue. When we started studying wind-related fatalities, the industry recognized that background mortality exists. For larger raptors, it's costly and not that useful to look at background mortality at control sites. But for some species (like burrowing owls) it may be important, especially if you are being asked to mitigate for mortality where background mortality is not insignificant.

Doug: I don't want to leave anybody with the impression that background mortality is a common issue. The Altamont is a unique wintering area for birds of prey. If raptors are a problem an issue in your project area, background mortality will could be an issue for smaller prey species.

Wally: Also, you can do necropsy work (to look for lead, rodenticides, blunt force trauma) on carcasses you are finding, rather than trying to look for carcasses in control sites.

Doug: We did find carcasses on ridges without turbines that we have no idea what killed them.

Wally: There are approximately 3,000 golden eagle fatalities per year from anthropogenic sources – lead, shooting, rodenticides, electrocutions, etc. We don't have as good information on other anthropogenic sources for other species.

Q: *How many of the fatalities found outside turbine areas could have been caused by turbines where animal moved offsite before dying? (How distinguish these from background mortality?)*

Doug: We were not able to look at that. The study was done during the period of time when the turbines were shut down. However, it is possible that birds may have collided with non-spinning turbines and then moved to an adjacent ridge without turbines.

Wally: It is necessary to keep control sites far enough away to ensure independence. Necropsies can fill a data need here as well.

Q: *How do you account for the dip in fatalities in the middle of your study period? Could it be related to inter-annual variation in bird use?*

Doug: The dip in the middle did not occur in the same year for each species, it occurred in different years for different species. We can't explain that dip in the middle with a single explanation for each species. There was a decrease in installed capacity over time, followed by an increase due to re-powering, but bird use (and mortality) does vary from year to year and there was a likely increase in detection probability over the last few year of the study.

Q: *Can you discuss how risk may differ for newer turbines vs. the older lattice-towers that provide hunting perches?*

Doug: Our study stratified the wind resource area by strata we called "BLOBs", which varied in the dominant turbine type and tower structure in the strata. We were therefore able to look at how various factors associated with each strata correlated with fatality rates in each strata, but that is an entirely different talk, so you should look up the final report.

Questions not addressed during study session Q&A:

For Doug:

Q: *How did the initial Smallwood-Thelander estimates stand up?*

A: The initial Smallwood and Thelander (2004) estimates were a decent "order of magnitude" estimate of raptor fatalities. The study clearly showed that there was an inordinately large number of raptors killed in the APWRA. However, they used a different guess (although based on more information) at what detection probability might be in a paper in 2009 using the same dataset, and came up with very different results. Estimates of Golden eagle and red-tailed hawk fatalities were now much lower, while kestrel and burrowing owl estimates went up. I think the kestrel and burrowing owl estimates were probably too high using either estimate, but there is no way to know for certain because detection probability was not estimated during the study.

Q: *The older Altamont turbines produce much less energy during low wind periods than modern turbines. Do you know how much these months-long shut-downs affected the economics of the wind projects?*

A: The actual amount of energy produced by each turbine would be a much better metric to use than rated capacity or installed rated capacity, but that information is proprietary and the wind companies would not make it public.

Q: *Was any consideration given to operating at night? Is there high use for resident raptors and migratory raptors at night?*

A: We were not able to conduct any experiments in which turbine operations were curtailed at night, or even measured at night versus during the day. However, given the high number of barn owl and great-horned owl fatalities, it would appear that night-time operation is just as deadly as daytime operation for those birds that are active at that time.

For Wally:

Q: *What effect does willingness to share data have on your study's results? Is there a way to estimate this source of bias?*

A: Many of the studies were a requirement of permitting and reported as such, so there should not be biases with those studies. One way to consider such a concern would be to focus on studies that were required to report results through permitting requirements to compare against voluntarily reported studies. The large number of studies available throughout the wind areas of the U.S. should also help minimize potential large-scale reporting bias.

Q: *With regard to carcasses used for bias trials: 1) any problems acquiring permits from states and USFWS to allow use of raptors for bias trials? 2) Were vultures included as surrogates and how were differences between vulture and non-vulture carcasses addressed? 3) Any information on scavenging rates for native bird carcasses that have been frozen for a long time?*

A: It is required to work with the USFWS and the states to ensure proper permits are in place for acquiring and using MBTA protected birds. A bigger limitation in using raptors is finding available raptor carcasses. You must coordinate with the USFWS in all cases. The typical protocol is to use carcasses that have not been frozen a long time.   I believe some studies that have used both vultures and other raptors and comparisons can be made in that case.

Q: *You did not report any uncertainty in your estimates. How precise are your estimates from method A and method B?*

A: Rather than modeling uncertainty, we assumed, due to conservative assumptions, that a reasonable range was captured by reporting both method A and B, since they both were based on conservative assumptions.

Q: *You adjusted percentage comp for detection of large vs. small, but other factors contribute to different detection rates among studies – namely different sampling fractions of the turbines. How was that accounted for?*

A: Probability of detection was determined based on the searcher efficiency rates estimated for the turbines sampled and so, in this way, sampling fraction of turbines doesn't affect the detection rates. We did not calculate the overall probability of detection "g" used in evidence of absence.

Q: *Any information on raptor fatalities during migration vs. during breeding or wintering seasons?*

A: there definitely were some patterns where wintering periods showed higher mortality for some geographic locations for some species (e.g. golden eagles, rough-legged hawks). However, we did not see strong peaks in mortality during migration similar to what we see for bats and nocturnal migrant songbirds.

Q: *Is it appropriate to compare the fatality rates with respect to their breeding population given that many fatalities are non-breeders?*

A: that definitely is a limitation in the analysis and makes it conservative.

Q: *What are the 90% + "other sources" of raptor fatality? Can you give a breakdown? Did you consider the effect of the drought on mortality?*

A: That has not been well documented for all species, but some recent estimates for golden eagle mortality suggest lead poisoning, rodenticides and illegal shooting are the most common anthropogenic source, and starvation is also a big source, especially for young birds.

Q: *With wind expanding so rapidly, are you concerned we could be approaching local or regional population-level impacts? What does this study tell us is needed to minimize this impact going forward?*

A: We did not look at local populations. Grainger Hunt has in the past investigated the likely impacts of wind energy in the Altamont on the local populations. This study was not designed to look at ways to minimize impacts, but there is a fair amount of literature on ways to reduce mortality of raptors, including micro-siting of turbines.

Q: *Your fatality data set does not include Bald eagles. Can you comment on what distinguishes Bald eagles in this regard? (Behavior?)*

A: The dataset did not include studies where bald eagle fatalities have occurred. We are aware of some bald eagle mortality and expect some published information in the next six months on risk of bald eagles to mortality.

Golden Eagles and Wind Energy: Predicting Interactions, Migratory Corridors and Range, and More

Moderator: Mark Martell, Tetra Tech, Inc.

Response of Golden Eagle Flight Altitude to Topographic Variation in California and Implications for Potential for Wind-Wildlife Interactions

Presenter: Adam Duerr, Division of Forestry and Natural Resources, West Virginia University

Authors: Adam Duerr (*Division of Forestry and Natural Resources, West Virginia University*), Leah Dunn (*Department of Public Policy and Administration, Boise State University*), Melissa Braham (*Division of Forestry and Natural Resources, Division of Geology and Geography, West Virginia University*), Tricia Miller (*Division of Forestry and Natural Resources, West Virginia University*), Amy Fesnock (*California State Office, Bureau of Land Management*), Douglas A. Bell (*East Bay Regional Park District*), Peter Bloom (*Bloom Research, Inc.*), Robert Fisher (*U.S. Geological Survey, San Diego Field Station*), Jeff Tracey (*U.S. Geological Survey, San Diego Field Station*), Todd Katzner (*U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center*)

PROBLEM / RESEARCH NEED

Planning renewable-energy development to minimize effects to sensitive species of wildlife requires knowledge of how those species use the environment. In the case of soaring species, such as eagles, it is helpful to understand how these animals select the altitude above ground level (AGL) at which they fly. Eagle flight behavior is related to topography, and these behaviors also affect risk when wind energy development is part of the picture.

Objectives
Increase our understanding of interactions between wind energy and golden eagles, by investigating how flight altitude of golden eagles changed relative to topography in each of California's topographically distinct Bird Conservation Regions (BCRs).

APPROACH

From 2011 through 2015, we collected telemetry (GPS-GSM and GPS-CDMA) data from 97 eagles tagged with cellular transmitters. Over three million locations were collected for these

birds over the study period. Of these, we identified about 180,000 flight points – defined as eagles moving at greater than 1 knot while above ground level. There was better coverage for some BCRs than for others, but the data analyzed do coincide with wind development interest areas.

We associated flight locations from these data with four measures of topography directly below each point. The first, a topographic position index, was categorized along a gradient that included valleys, gentle slopes, steep slopes, and ridges. The second, a topographic roughness index, was categorized into 5 classes that included smooth or flat areas, and areas with slight, low, moderate and high roughness. We also included measures of slope and aspect of the terrain.

Our response variable was flight AGL. We looked at how this varied, both regionally and as a function of four topographic measures:

- Percent slope
- Aspect (Euclidean vectors of northness and eastness),
- Topographic position
- Topographic roughness – smoothness of the terrain

FINDINGS

Unpublished results suggest that flight AGL for golden eagles differed by BCR and, in each region, responded distinctly to topographic position, slope and northness (north-south component of aspect). In contrast, response to topographic roughness and eastness (east-west component of aspect) did not vary among BCRs.

Empirical estimates of eagle flight AGL were highest over the Sonoran and Mojave Desert BCRs (250 ± 112 m; grand mean by bird ± SE); intermediate over the Sierra Nevada (234 ± 178), Coastal California (227 ± 150) and Great Basin BCRs (210 ± 147) and lowest over Northern Pacific Rainforest BCR (161 ± 104 m). Model results projected eagle flight AGL was highest over valleys and gentle slopes and lower over steep slopes and ridges. Flight altitude tended to decline as you move up towards the ridge. In the Sierra Nevadas, AGL was much higher over gentle slopes than for other BCRs.

For all BCRs, flight AGL was greatest over level terrain, intermediate over slightly rough terrain, and lowest over terrain with low, moderate, and high roughness. . Flight AGL also decreased as slopes became steeper, with the strongest effects in Coastal California and the Sonoran and Mojave Deserts. The compass direction of slope also influenced flight altitude, such that flight AGL was higher on east- and south-facing slopes although this latter effect varied by region.

CONCLUSIONS / APPLICATIONS

Flight AGL appears to be related to two types of supplemental updrafts that eagles use, thermal and orographic updrafts. Thermal updrafts allow eagles to soar at high AGL and occur where

eagle flight AGL was highest (gentle slopes that faced east or south). Orographic updrafts limit eagle soaring to low AGL and occur and occur where eagle flight AGL was lowest (steep slopes and ridges with rough terrain).

Risk of eagle-turbine interactions occurs when flight AGL overlaps with the rotor swept zone of turbines, generally ~20 – 130 m AGL. Although eagles may have flown at the AGL of the rotor-swept zone in all settings, our data suggests that this occurred most frequently over steep slopes and ridges – especially in the Coastal California and Mojave and Sonoran Desert BCRs – and over terrain that had moderate to high roughness. Developers may be able to use this information to site turbines where flight AGL is likely to be relatively high: that is, locations with low slope values on ridgelines with south-east aspects. Likewise, in cases where turbines have already been built, managers may implement cost-effective mitigation strategies targeted at relatively more risky areas to minimize turbine blade-eagle collisions.

Next steps would include refining our understanding of risk by incorporating additional drivers of flight altitude, such as weather and other temporal factors.

Questions & Discussion

For All Panelists:

Q: *What do you see as the priority questions?*
- Identifying ways to improve siting so we consistently put turbines in low-risk sites is a priority.
- Overall risk modeling so we can understand relative risk and how it affects placement of turbines is a high priority.

For Adam Duerr:

Q: *What happens when you add prey (such as a ground squirrel colony in a valley) as a driver? Could low flight altitudes in steeper or rougher terrain be partly due to better hunting habitat in these areas, and is there a way that you can analyze the data to investigate that? How do you incorporate that into the topographic analysis for siting plans?*

Adam D: Hunting behaviors – using contours in the landscape for concealment – can mimic the same patterns you get from orographic updraft. Differentiating those behaviorally can be really difficult. Maitreyi Sur (Department of Biological Sciences, Boise State University) has a paper on identifying various behaviors (such as hunting) using telemetry data. So yes, there are ways to do that, but apart from being academically interesting, the applications of this understanding to relative to risk may not require that.

The other way to approach this is to incorporate resource selection functions that use a wide array of habitat characteristics to get at questions like how presence of prey affects risk. Although, the information on prey abundance is not necessarily available.

Q: *As turbine height increases, your data shows risk will also increase in California. Will you add this to your analysis?*

Adam D: We will not explicitly add this to our analysis. Our predicted flight altitude tools can be used by developers to evaluate risk, given [any] turbine height and topography.

Genomic Resources for the Management and Conservation of Bald and Golden Eagles

Presenter: Ronald Van Den Bussche, *Oklahoma State University*

Authors: Ronald Van Den Bussche (Oklahoma State University), Megan Judkins (Oklahoma State University/Grey Snow Eagle House), Brian Couger, Stephen Clark (Oklahoma State University), Wes Warren (McDonnell Genome Institute, Washington University)

PROBLEM / RESEARCH NEED

Partitioning of genetic variation within and among populations throughout a species' range in order to delineate the biologically relevant boundaries within that range should constitute the first step in any conservation or management program. This critical step would inform the wildlife managers, biologists, and policy makers of the "units" they are attempting to conserve or manage while also setting the biological and theoretical foundations for future decisions.

Unfortunately, elucidating the genetic variation within and among populations of bald (*Haliaeetus leucocephalus*) and golden (*Aquila chrysaetos*) eagles has proven exceedingly challenging. Currently, the U.S. Fish & Wildlife Service is managing these species either via Eagle Management Units, which are different for the two species, or via flyways, which are the same for both species. However, the existence of discrete population units for either species, if they exist, has yet to be evaluated with genetic data. The fact that we don't know best way to manage eagles makes it difficult to evaluate population structure, gene flow, parentage, relatedness, genetic and adaptive variation. Genetic markers can address these issues and so aid in management and conservation efforts which are critical in light of increased anthropogenic stressors – including climate change, poisoning, habitat loss and fragmentation, electrocutions, and collisions with wind turbines.

Objectives

The purpose of this study was to utilize a genomic approach to evaluate these competing hypotheses for eagle management units as well as a purely genetically based delineation of eagle populations. Addressing this overarching objective will allow for mitigation of population

losses due to unintended "takes" of eagles at wind farms by determining the natal origin of individual eagle fatalities.

APPROACH

We utilized a reduced genomic sequencing of 200 bald eagle genomes and 32 golden eagle genomes, resulting in approximately 1.5 million genetic loci, or Single Nucleotide Polymorphisms (SNPs) for golden eagles, and 1.8 million SNPs for bald eagles. Such "DNA zipcodes" had been developed for other species, but had not been attempted previously for eagles. We reduced these to a smaller number of SNPs (38,305 for golden, 50,879 for bald), including intergenic regions and ecologically relevant genes.

The 89,184 gene loci can be placed on a "gene (SNP) chip" that can be used to determine sex and other genetically-determined features from a DNA sample. After filtering all the SNPs, the program determines how many discrete genetic types of golden eagles are present in a group of individuals.

FINDINGS

Our analysis of 131 golden eagles yielded five groupings that correspond to a previous study by Doyle. For bald eagles, we came up with seven populations using a group of 154 individuals. Based on this analysis, we were able to determine the mix of populations found in different areas. For example, the 22 bald eagles sampled in Oklahoma included individuals from all seven different populations.

CONCLUSIONS / APPLICATIONS

This study represents the first population genomics approach for bald and golden eagles. Once we come up with populations we agree on, these species-specific SNP Chips will allow for the delineation of biologically relevant population boundaries as well as assign individuals of unknown origin to their natal area. The same approach has been taken with falcons and other species, so its feasibility and value has been established.

It is worth noting that much of this research was funded by the Iowa Tribe of Oklahoma, which is made up of fewer than a thousand individuals. The Iowa and other tribes have made this research possible because they value these birds but also recognize need for wind energy.

Questions & Discussion

Q: *How does the bottleneck that bald eagles went through – a lot of translocations in late 1980s – how does that impact your analysis, and can you account for that?*

A: Data from Oklahoma clearly shows that birds came from Florida, Maryland/New Jersey. We know there were translocations from the Midwest, but also from Canada. Those birds in New Jersey and Maryland have some very unique genetic contributions that we suspect came out of

Canada. We can account for those translocations with our data, and we also are looking at birds from those areas that were not affected, such as Yellowstone.

Golden Eagle Migration Corridors along the Rocky Mountain Front and Intermountain Flyways

Presenter: Adam Shreading, Raptor View Research Institute

Authors: Bryan Bedrosian (*Teton Raptor Center*), Robert Domenech, Adam Shreading (*Raptor View Research Institute*), Matthew Hayes (*Lone Pine Analytics*)

PROBLEM / RESEARCH NEED

Golden eagles (*Aquila chrysaetos*) have been receiving increased attention in the western United States due to an increase in anthropogenic population threats, including wind and other industrial energy developments. Conservation of migratory golden eagles hinges on knowledge of threats within breeding ranges, migratory corridors, and over-wintering areas. Often, understanding threats along migration corridors can be difficult due to the short temporal use of migration paths and because pathways can often be dispersed across the landscape.

Objective

Identify critical corridors for eagles migrating over Rocky Mountain front.

APPROACH

We used satellite tracking data from three separate studies that outfitted golden eagles with transmitters. Two of the studies involved wintering populations and one looked at fall migrants at Nora Ridge. We gathered data from 35 individuals, including from 21 adult and 14 sub-adult golden eagles, to estimate key migration routes and bottlenecks for migratory golden eagles wintering or passing through Montana, with an emphasis on the Rocky Mountain Front.

Many studies estimate the intensity of use (utilization distribution) of birds on summer and winter ranges using kernel density estimators to estimate the probability of relative frequency of occurrence; these estimators do but not account for the temporal structure of observations. For each migration event we created individual dynamic Brownian Bridge Movement Models (dBBMM) to generate utilization distribution of migratory movements in both space and time for individual birds. We also created a population level migratory pathway estimate to determine key migration corridors and bottlenecks by summing the individual dBBMMs after accounting for age and study location.

The dBBMM looks at the probability of an animal's occurrence between subsequent locations depends as a function of the previous and subsequent location, the elapsed time between points, and the typical flight speed of eagles. Given the same elapsed time between locations, the further apart those locations, the straighter the line we assume that the eagle was flying. We created 99% confidence contours around these lines.

FINDINGS

The data included a total of over one hundred migratory events, allowing us to map where these birds spend their summer in Alaska and northern Canada, and their annual migration patterns. Most individuals start heading south from mid-September to mid-October. Sub-adults start south earlier. We found no difference in terms of gender. Spring migration presented the reverse pattern, with breeding adults starting earlier.

Individual migration journeys span 2000-4000 km on average. The longer the distance they traveled, the longer it took them, with the average of migration lasting 44 days (4-8 weeks). Migration movement happens during the day, starting mid-morning, with birds starting to roost in the late afternoon. Eagles make the spring migration more quickly – not because they are flying faster, but because they spend more time flying each day, traveling longer into the late afternoon.

Eagles are very faithful to the routes that they use, so we used one spring and one fall to plot each eagle's route.

The Continental Divide is the "highway" for both fall and spring migration. Many of the birds we tracked wintered in Montana, so we had to tease out information for the birds that wintered further south. We compared our migration tracks with nine western count sites. The three along the Continental Divide have the highest counts, which confirms it is the main corridor. We also noted that the counts have declined over the past several years.

CONCLUSIONS / APPLICATIONS

Management implications for wind energy can be illustrated by mapping migratory corridors with wind energy resource areas. These models can be used for future risk assessments for developments and conservation measures for golden eagle migration routes.

Questions & Discussion

Q: *Do you plan to collaborate with researchers capturing birds elsewhere in the West? We know areas in SE Idaho and Central California are high use by wintering golden eagles, but none of the birds in this study go up to those areas.*

A: While we are interested in collaborating with other researchers, our study hopes to identify key areas in our region rather than a complete picture of North America as a whole.

Q: *How much work is planned, or has already been completed, on the eastern population of wintering and breeding golden eagles? (Genetic uniqueness, migration routes, use of topography, other?)*

A: We can make comparisons. Our group has done risk modeling in the eastern U.S., so we can see if they are comparable, in which case it may be reasonable to extrapolate. With the paucity of data elsewhere, we are sometimes stuck with extrapolation, which is better than using no data at all.

Todd: principles are easy to extrapolate, the details are not.

Q: *Do you plan to continue this research?*

A: Yes – in Alaska, planning to get more individuals from Travis [Booms]. We hope to have a significantly larger sample size next year.

Q: *Were any of the birds you captured residents (that is, did not exhibit long-range seasonal movements)?*

A: We captured birds from three different areas – some were resident birds, but we only analyzed data for migrating birds.

Q: *Are birds especially at risk for collision during migration – what do your results suggest?*

A: Yes, depending on the project siting and individual bird behavior.

Additional questions not addressed during session Q&A:

Q: *Did you consider using bootstrapping to simulate location of point count?*
No.

Evaluating and Adapting Surveys designed to Predict Wind-Wildlife Interactions: a Simulation Approach Focused on Golden Eagles

Presenter: Todd Katzner, USGS Forest and Rangeland Ecosystem Science Center

Authors: Maitreyi Sur, James R. Belthoff (*Department of Biological Sciences, Boise State University*), Todd Katzner (*U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center*)

PROBLEM / RESEARCH NEED

Monitoring is essential – not only for compliance with regulatory requirements, but for evaluating existing management practices and estimating occupancy, abundance and survival of different species. However, monitoring is most helpful if it is done well, using methods appropriate to the species and the research objectives.

Point count survey (PCS) methods were originally designed to count songbirds. The observer surveys an area from a designated observation point, using a form to log observations of whatever species are being counted. This method works well for things that are small and easy to hear and see, but it not so well for eagles, which are characterized by low densities, widely spaced nests, and rapid movement. The solution typically incorporated into eagle conservation plans is a modified point count surveys. However, it is not always clear to what degree the data collected at on-site point counts relates to actual eagle use of an area.

Objectives

The aim of this project was to understand the relationship between potentially observed and actual use of simulated wind project footprints by individual eagles, using high-resolution GPS-GSM telemetry data to measure eagles' actual use of the Mojave Desert region.

APPROACH

We focused on California's Desert Renewable Energy Conservation Plan (Barstow, Ridgecrest) area, which is estimated to encompass 74 occupied golden eagle territories. There is a huge amount of telemetry data that have been gathered over the years in this area. We focused on data from 2012-2013, using telemetry data collected every 15 minutes from seven territorial eagles and six fledglings tracked in the Mojave Desert. These are territorial eagles that mostly stayed within the area over that time period.

We then converted these data into hypothetical project footprints and generated hypothetical 800-m point count survey data within those footprints for a variety of potential point count sampling strategies, intensities, and project footprint sizes.

1. Three point count sampling strategies: random, systematic, stratified
2. Two sampling intensities: 30% or 60% area coverage
3. Project footprint sizes: 20, 40, 90 and 180 square km project footprints

We then calculated the error due to sampling – that is, the time an eagle spends within these point count areas vs. total time within the project footprint.

FINDINGS

We found that in 2012, three-way interactions among month of year, sampling intensity and size of the project footprint influenced the effectiveness of surveys in describing use of project footprints. Similarly, in 2013, two-way interactions between month of year and sampling intensity and between month of year and size of project footprints influenced the effectiveness of the surveys.

We also found that when sampling frequency was reduced, the effectiveness of the surveys was drastically reduced. With 60% coverage, point counts did a better job of estimating time spent in the project area. On smaller project footprints, random sampling did better. We also evaluated how survey results would vary with sampling frequency (daily, weekly, bi-weekly, monthly or quarterly), keeping project footprint size constant. With daily sampling, error due to sampling was low. As the sampling interval increased, error increased.

CONCLUSIONS / APPLICATIONS

Although our work focuses on individual eagles (not eagle populations), our analysis shows the utility of simulations to test the efficiency of survey methods and improve surveys at wind energy facilities by considering the context-specific way point counts are laid out on the landscape. An adaptive sampling design approach could, for example, use resource selection functions to stratify sampling according to habitat type. Monitoring protocols that have flexible design based on variations in eagle behavior could also account for annual variation in behavior.

Questions & Discussion

Q: *How much work planned or already completed on eastern population of wintering and golden eagles?*

A: There has been a fair bit of research [see literature cited below]. We have a decent idea about their genetics. Understanding distribution, migratory corridors, winter ranges.

Q: *What is an acceptable level of error due to sampling? Why do you think error due to sampling would be normally distributed?*

A: Not a great answer to that. Did not highlight – a fair number of our errors due to sampling were close to 1, which is not what we want. Would rather see a perfect correspondence

between point counts and eagle use of project footprints. Don't have a useful solution at this point.

Q: *In light of your findings, what are your recommendations for refining the 800 m radius used by for USFWS plot approach?*

A: We have a paper in review. Have tried to dodge that point a little bit. The reality is that it probably is very important to account for seasonal variation in eagle studies. We know we need to account for that with migratory birds, but also for resident birds. Weakness in our dataset doesn't allow us to do that right now. The greater number of days and longer number of hours per day, the more effective those point counts will be. That's expensive – there is no easy fix. Micro-siting might obviate some of that however.

Q: *Based on your analysis, do you think that monthly surveys are sufficient to measure use at lower-use sites? At higher-use sites?*

A: It is clear that monthly sampling has a dramatic increase in error due to sampling.

Q: *If point counts are not that effective, would resources be better spent on telemetry and genomic research to understand overall eagle movement and wind siting?*

A: It depends on your research goals. If your question is to understand movement and behavior, telemetry is good. But if you need to know use and abundance, some kinds of surveying is required.

A [Adam Duerr]: one issue that doesn't come up is that these surveys for eagles are time-specific. Territory occupancy changes over time; it will not stay the same over the life of a 30-year project. It is better to understand the environment and how eagles use that environment than to focus on point counts.

Q: *The steepest point of the sampling error curve due to sampling frequency was between daily and weekly – were intervening frequencies (2 or 3 counts per week) looked at?*

A: No, we just looked at those four scales. The curve probably doesn't change.

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Overview of USFWS Western Golden Eagle Team Risk Assessment and Conservation Planning Program

Presenter: Brian Woodbridge, US Fish & Wildlife Service

[[presentation]]

Authors: Gary Williams, Brian Woodbridge, Todd Lickfett, Geoffrey Bedrosian (*U.S. Fish and Wildlife Service*)

PROBLEM / RESEARCH NEED

Expanding renewable energy development in the Western United States has led to increased regulatory and conservation issues concerning golden eagles (*Aquila chrysaetos*). In June 2013, U.S. Fish and Wildlife Service Regions 1, 2, 6 and 8 established the Western Golden Eagle Team (WGET) to address these issues. The initial team has since evolved into a wider collaboration pursuing a broad range of activities within the context of existing U.S. FWS policy, regulations, and guidance.

- WGET's role is to develop a suite of science-based products for use in project siting (ECPG Stage 1) and strategic compensatory mitigation (Stage 4).
- Develop landscape-scale strategies for golden eagle conservation.

Specific Objectives

There is a long, complex list of factors wind developers need to consider when prospecting for project sites. WGET's goal is to develop tools that can be used to identify relative levels of risk as early as possible in the site prospecting process – at the desktop review stage.

1. Develop predictive models of golden eagle distribution and relative abundance during all seasons and life history stages.
2. Conduct spatially explicit evaluation of risk factors including but not limited to energy-related risk factors (e.g., electrocution, collision with vehicles, contaminants).
3. Develop information resources to support management of golden eagles and their prey.
4. Combine the above into eco-regional conservation strategies that apply what we know at the eco-landscape scale.

APPROACH

Working in collaboration with scientists and managers from state and federal government, academic, Tribal and private organizations, WGET is developing a range of assessments and information resources intended to provide additional foundation for conservation strategies. Our approach to modeling for conservation planning is characterized by:

- Looking for reliable *spatial prediction* of distribution and relative abundance of eagles, during all seasons and life history stages
- Using best available data "plus" – i.e., filling the gaps by leveraging and expanding on field research others are doing
- Emphasis on evaluating the performance of the models
- Anticipating that new and better data will come in, and that we will need to adapt and improve the models through implementation and feedback.

FINDINGS

The rest of this presentation reviews WGET's work on each of our four specific objectives.

Predictive models of Golden Eagle distribution and relative abundance

WGET's predictive modeling approach looks separately at eagles in their breeding habitat, wintering areas, and the movement routes between them. There is, of course, overlap among these areas that adds complexity to the modeling approach.

- ***Breeding habitat models***
  Reliable prediction of relative habitat suitability (or relative density of use) at the scale of breeding territory requires species distribution models that consider such variables as terrain, aspect, local elevation, land cover, primary productivity, climate, anthropogenic features, orographic uplift and thermals. Each region has different combinations of features that determine eagle presence or use, so these models are necessarily ecoregion-specific.

  Spatial data consists of nest site records – WGET has compiled over 100,000 nest records from 154 data sets. Some portions of our ecoregions had few or poorly distributed data. From 2014 to 2016, WGET supported nest surveys in specific parts of ten western states where nest data were poor (Texas, for example, had no data). Approximately 314 new nest locations were used to refine models and evaluate model performance in these targeted areas.

  Ecoregional models were developed for the Northwestern Great Plains, Wyoming Basin, Central Basin and Range, Northern Basin and Range, and Columbia Plateau. Models for the Colorado Plateau, Arizona/New Mexico Plateaus, and the Western High Plains/ Southwestern Table Lands are currently under development.

  Field evaluations of model predictions indicated that the models do a good job of predicting breeding habitat density of use.

- ***Mid-winter landscape use models***
  We took a "big-data" approach to modeling mid-winter landscape use, compiling data from California Avian Data Center searches, Rocky Mountain Avian Data Center surveys, eBird datasets, and the U.S. FWS mid-winter Bald Eagle survey. Data were aggregated

for 10km by 10 km cells. A Historic-Data Imperfect Detection Model was used to determine mean occupancy rate per cell, and a Boosted Regression Tree Model was used to improve predicted occupancy model fit with environmental variables.

The predictive accuracy of our models was tested against independent datasets from Oregon, Idaho, and Nevada. Landscape models predicted relative abundance with 84% accuracy. Additional winter survey data (ideally from the plains in Texas, Oklahoma, and the Dakotas) are being sought for further model evaluation.

- ***Movements and migration models***
  Developing predictive models of golden eagle movement and migration between and on the birds' breeding and wintering ranges is WGET's most ambitious modeling project. Our objectives are to describe and map patterns of movement and develop a predictive model of movement "habitat" – that is, what landscapes and ecological conditions are disproportionately used by migrating eagles?

  We compiled telemetry data (ARGOS, GPS, GSM) from collaborators throughout North America for meta-analysis. We identified landscapes where telemetry had not been conducted, and from 2014 to 2016, WGET deployed 72 GPS PTTs on golden eagle nestlings to fill gaps in Washington, Oregon, California, Nevada, Arizona, Idaho, Utah, and Montana. USFWS added another 65 transmitters on nestlings in Colorado, Wyoming, Montana, South Dakota, Nebraska, and Texas in 2013-15. With the help of 28 collaborators we were able to track just under 800 eagles at almost 5 million locations. (We are always looking for more data – especially from the central U.S. – and are able to incorporate the data without infringing on privacy of records.)

  The next step is to describe and map the patterns of movement. We are using a Bayesian state-space switching model ("BSAM" r-package) to discriminate directed long-distance movements ("transiting") from localized movements ("settling"), and developing separate resource selection function (RSF) models for each of these behaviors.

  The predictive model of movement areas is still a work in progress. We are comparing alternative modeling methods, and will evaluate model performance with independent data from new deployments.

The final step in predicting the relative risk of golden eagle exposure to wind (or other) development will be to create composite maps of each ecoregion incorporating outputs from the three predictive models – breeding habitat, winter habitat and movement and settling habitat.

Spatially Explicit Evaluation of Risk Factors
This area of WGET's work focuses on identifying where it makes the most sense to prioritize a given mitigation. This involves evaluation and predictive modeling for various types of stressors,

including electrocution, contaminants, collisions on roads, disturbance, and disease and parasites.

- **Electrocution**
  This is an overall synthesis, looking at risk from the landscape level all the way down to the level of individual poles. How to improve and prioritize retrofitting efforts? We developed a predictive model of landscape-scale electrocution hazard, using the density of power poles as a surrogate for electrocution hazard. We then overlapped that model with the breeding and winter models for golden eagles to map risk. Our first cut at developing a risk model has been well-validated by comparison with a large electrocution mortality data set from Wyoming.

  Contaminants Here the objective is to predict potential contaminant (lead, for example) exposure from multiple sources such as hunter-killed big game and recreational shooting of ground squirrels/prairie dogs and coyotes. States have good records of where hunter game kills occur, so we can overlay that with models of golden eagle distribution and movement routes to evaluate where eagle use areas intersect with game carcass locations where eagles could be exposed to lead shot. We are also quantifying lead exposure resulting from organized shooting of ground squirrels; we are still analyzing data from golden eagle nestlings in these shooting areas. The fact that that this an organized recreational activity offers opportunities for mitigation via collection and disposal of squirrel carcasses and potentially fostering use of non-toxic ammunition.

- **Collisions with vehicles**
  This is a spatial model of relative risk based on road characteristics (traffic, speed, terrain), big game winter range, migration route models, jackrabbit habitat, and golden eagle winter and movement models. We are evaluating the model using state-identified road segments with history of vehicle-eagle collisions.

Information resources for habitat management and mitigation

- **Prey resource management**
  WGET has developed number of information resources that deal with eagle diets, prey resources, and prey management. These assessments are organized by eco-region to account for the wide range of habitats and prey species used by golden eagles across the West.

- **Nest site management**
  WGET is reviewing and compiling information on management of Golden eagle nest sites, including moving nests, improving or restoring nests, and creating artificial nests. For example, golden eagle nest sites and territories are being lost in areas where cottonwood trees are dying out and not regenerating due to grazing and dewatering. Eagles will use artificial nest sites, cottonwoods can regenerate fairly quickly, offering

two possibilities for mitigation. A study looking at the effect of exposure and high temperature on golden eagle nest success in SE Idaho suggests another opportunity for management to improve nesting success.

- ***Disturbance effects and management***
  WGET is currently supporting three efforts looking at disturbance effects and management opportunities:
  - A review and synthesis of research
  - Modeling population effects of disturbance to breeding
  - Biological consequences, behavioral mechanisms, and management implications for recreational disturbance to golden eagles

ECOREGIONAL CONSERVATION STRATEGIES

Ecoregional conservation strategies combine ecoregion-specific models, risk assessments and information resources to look at conservation planning in a more landscape specific way. This is highly collaborative work, requiring participation from state and federal agencies, Flyways, research institutions, industry, Tribes, and non-governmental organizations.

"Customers" for this work include:

- **Federal land management agencies** responsible for Land Management Plans; NEPA compliance for energy, transmission development; recreation development
- **Energy development industry and consultants** seeking information to support development siting, risk assessment, and mitigation approaches
- **County, municipal, and private landowners** required to develop or implement habitat conservation plans or conservation easements
- **Nongovernmental organizations** involved with land trusts, conservancies, **or** landscape planning

Strategies for the Northern Basin and Range, Wyoming Basin, Central Basin and Range and Northern Great Plains are in progress. We expect to begin putting tools online this winter, hope they will become part of NREL and other "desktop" tools. Relevant risk assessment and decision support tools *may be* incorporated into future versions of FWS' Eagle Conservation Plan Guidance.

CONCLUSIONS / APPLICATIONS

Effective implementation of risk assessment and decision support tools, and conservation measures is an adaptive process. To continue to evaluate and refine these products, WGET and partners will be reliant on feedback from practitioners, incorporation of new research, and targeted field surveys to fill data gaps.

Q: *Identifying low-risk sites – is that an explicit outcome that you can help with?*

A: Many of the models that WGET has developed/is developing are intended to quantify relative risk. For example, our models of breeding habitat suitability will reliably predict relative density of eagle territories, but are not estimates of actual density. At what point does looking at relative degree of risk fit with categorizing a given site as "low-risk"? We are actively working with others in FWS to evaluate various metrics that can be used to support "low risk" conditions for development. We do hope that this work will to contribute to that.

Additional questions not addressed during session Q&A

Q: *When do you anticipate being able to share model results (GIS data) publicly? If you will not be sharing data, will methods (suitable habitat model) be published?*

A: WGET's breeding habitat suitability models for about 2/3 of the western U.S. are complete and being reviewed and prepared for release to the public during late winter/spring of 2017. The models, model procedures and spatial data will be made available via WGET's web site and USFWS ECOS-IPAC site. We also will be publishing the suite of models in 2017. The winter habitat suitability model will be released on the same schedule. The movement/migration models are still under development and

Q: *Is there a similar golden eagle team for non-renewable industries? If not, why not?*

A: The objectives of the Western Golden Eagle Team cover a broad range of conservation concerns from electrocution and contaminants to prey populations and nest disturbance. While the impetus for the Team's formation was to support siting and mitigation for wind development, our risk assessments, decision support tools and conservation measures apply equally well to planning other renewable and non-renewable energy development, as well as land management planning.

Q: *Anti-lead work has been occurring in UT, AZ & CA for condors for several years. We know where these birds got high lead levels because a huge portion of the population is collared. How do you plan to determine the source where high lead was ingested for eagles? Management should focus on locations where high heavy metal toxicity risk occurs.*

A: Our current efforts are aimed at identifying & modeling sources of lead, and overlaying these sources with predictive models of golden eagle abundance to identify areas with relatively higher levels of exposure. It is unlikely that golden eagles will be monitored at the intensity that would be required to specify actual exposure sources (as with condors). However, results of our work and others (Bedrosian in Wyoming, for example) are helping to identify areas for prioritization of a variety of lead remediation efforts.

Q: *Where is all the data housed? Who is holding all the satellite radio-telemetry data?*

A: The MANY collaborators who are providing telemetry data to WGET's meta-analysis of golden eagle movements have supplied a grid of processed data to a third-party analyst through a series of data-sharing agreements. The USFWS does not house the raw telemetry locations, but participates in directing the analysis along with many of the researchers contributing data.

Q: *If I understand correctly, you say that there are known landscape features that would determine golden eagle use and therefore risk factor, yet the Bayesian only seems to indicate risk based on observed (or theoretical) use. How is this reconciled?*

A: Landscape features such as land cover, terrain, climate and wind uplift can be used to develop reliable predictive models of relative use by eagles, but such models are intended for use at larger spatial scales than the footprint of a proposed wind development. At fine scales of resolution, the uncertainty inherent to model estimates could lead to significant under- or overestimates of eagle exposure. This is why the Service's Bayesian fatality estimation model relies on field-measured data on eagle use.

Q: *How much work is planned, or has already been completed, on understanding the eastern population of wintering and breeding golden eagles: genetic uniqueness, migration routes, use of topography, etc.?*

A: Todd Katzner's group has conducted and published considerable work regarding migration and movements of eastern golden eagles. WGET will include eastern golden eagles in our North America-wide meta-analysis of movement data, but we are analyzing western populations first.

Using Modeling to Inform Siting of Wind Energy at a Landscape Scale

Moderator: Taber Allison, American Wind Wildlife Institute

Low Ecological Risk Wind Energy Development Areas Analysis

Presenter: Jim Hays, The Nature Conservancy

Authors: Jim Hays, Chris Hise, Jay Pruett, Brian Obermeyer (*The Nature Conservancy*)

PROBLEM / RESEARCH NEED

The Nature Conservancy (TNC) is a nonprofit, non-governmental organization, and an accredited land trust. We work with natural systems at the landscape scale, with a focus on maintaining self-sustaining natural systems, protecting biodiversity and minimizing habitat fragmentation. We have chapters in all 50 states and are also engaged in 70 countries.

TNC has been working with wind development in the Great Plains for many years. The Kansas and Oklahoma chapters began collaborating on a GIS assessment in 2013 to help address some of the questions we had been asked, over time, regarding wind siting in the two states. We started out talking about mitigation, but came to the conclusion that there is significant development potential in low-risk areas, and that ambitious wind development goals may be fully realized (and far surpassed) by siting projects exclusively in areas with low risk of wildlife conflicts.

While we recognized that risk cannot be entirely eliminated, due to data gaps, impacts to wide-ranging species, and so forth; we expected that this type of spatial assessment could reduce administrative burden, risk profile, and total cost relative to the standard mitigation hierarchy approach. Such a product could facilitate the efficient build out of wind energy while minimizing risks to wildlife.

Objectives

Develop a spatial assessment based on existing literature that greatly reduces the potential for major wildlife conflicts, using TNC's 'Development by Design' approach. Minimize the use of statistics and complex map outputs to make a product that a broad audience of stakeholders –

wind developers, local government officials, power purchasers, land owners, etc. – can easily understand and use to realize ambitious wind development goals.

APPROACH

Our study area was fairly narrow in scope initially, including parts of Kansas, Oklahoma, and some of the Texas Panhandle. It was eventually broadened to include all of Kansas, Oklahoma and the Panhandle. We chose 12 key wildlife areas (nature.org/sitewindright):

- Whooping crane stopover sites (as identified by USFWS)
- Bald eagle nesting sites (within 1.6 km – along the Lower Kansas and Arkansas River Systems)
- Lesser prairie chicken – (info from WAFWA and wildlife agencies)
- Greater prairie chicken optimal habitat – native habitat – again 1.6 m buffer
- Bat caves – focus on buffers up to 32 km from known Mexican free-tail bat caves (a few in Kansas, more in Oklahoma) and a known colony of Gray bats
- American burying beetle conservation priority areas (identified in OK by USFWS)
- Other threatened and endangered species (coordinate with state and federal agencies)
- Playas – identified "high quality playas," or temporary wetlands – buffered up to 800 m within the whooping crane corridor and 400 m outside that corridor
- Globally Important wetlands
- Protected and managed areas (e.g., state/federal lands, military installations, refuges, preserves, etc.)
- Kansas Tallgrass Prairie Heartland – Flint Hills of Kansas

We also included airfields, special use airspace, NEXRAD air stations, existing wind facilities, excessive slope, developed areas, water and wetlands and poor wind resource/transmission; in our Low-Risk assessment. See the 'Descriptive Paper' (Appendix A) on the website for more insight into the 12 Key Wildlife areas and the Potential Engineering and Land Use restricted areas.

FINDINGS / APPLICATIONS

The resulting map indicates that there is potential for *210 GW* of additional wind energy capacity in areas that would be considered "low-risk" from a wildlife/landscape habitat perspective. These include wind resource areas in 64 of Oklahoma's 77 counties and in 99 of Kansas's 105 counties that are not yet developed. (Map also shows existing wind energy development.) This represents nearly three times current nameplate wind generating capacity in the U.S, and over five times the current electric generating capacity from all sources in Oklahoma and Kansas, as of 2015.

TNC has completed a similar assessment for the Northern Great Plains, using slightly different methods. Together, with this mapping tool (which can be downloaded in ArcGIS format from TNC's SiteWindRight website) these two assessments encompass much of the high wind resource area in the central part of the continent.

Using a Landscape Design Conservation Planning Process to Assess and Plan for Wind Energy Development in the Western Great Plains, USA

Presented by Anne Bartuszevige, Playa Lakes Joint Venture

[[presentation]](presentation)

Authors: Anne Bartuszevige, Kyle Taylor, Alex Daniels, Michael Carter *(Playa Lakes Joint Venture)*

PROBLEM / RESEARCH NEED

Playas are depressional wetlands. They often are dry; have no connection to surface waters, and as lowest area in watershed, they fill when there is an inch or more of rain in a 24-hour period. There are 80,000 of playas found throughout the Western Great Plains, and they are important in recharging the High Plains Ogallala aquifer, supporting plants and animals that in turn support migrating wetland birds.

The U.S. Great Plains region has been referred to as the "breadbasket of America" because it provides a high proportion of the agricultural products grown in the U.S. Increasingly the region is being called on to provide a larger proportion of the energy needs of the U.S. as well. In addition to large oil and gas resources, Nebraska, Colorado, Kansas, Oklahoma, New Mexico and Texas all have some of the highest wind energy potentials in the U.S; thus there is a high rate of wind energy development occurring in the region. This region also provides critical habitat for migrating wetland birds in the Central Flyway, so conservation of grassland and playa wetlands in the region are of utmost importance for maintaining populations of these birds.

Humans are on – and acting on – the landscape; our energy, economic and social needs and interests have to be balanced with conservation interests – in this case, the preservation of ecologically important playa lakes.

Objectives

The Playa Lakes Joint Venture (PLJV)—a non-profit conservation organization dedicated to conserving the playas, prairies and landscapes of the western Great Plains for the benefit of birds, other wildlife and people—is using landscape design to help conservation partners in their conservation planning decision making.

<u>APPROACH</u>

Landscape design is a conservation planning process that integrates societal goals and values with biological goals, and uses sound science based in landscape ecology to describe future scenarios where specific and measurable biological goals can be attained. PLJV is one of 22 joint ventures in the US and Canada. It is unique in that we are a nonprofit involving state game/wildlife and parks departments, federal agencies, conservation organizations, and energy producers.

This is a stakeholder driven process where both conservation and economic interests are represented. Slide #6 provides a landscape design flowchart. The joint venture is very goal oriented; the PLJV Management Board and partners continually check in as to how we are doing towards meeting quantified goals. For wind energy and waterfowl, our goal is to provide at least 20% of the diet of migrating waterfowl from native seed sources.

We modeled wind energy development suitability using wind turbine locations from the Federal Aviation Administration digital obstruction database and a suite of physiographic, anthropogenic and climate variables to populate the model. Access to transmission lines also was a driving factor. The output is a continuous, 30-meter resolution raster surface representing suitability for wind energy development on a 0 to 1 scale. (Slide #9 shows habitat suitability for wind energy.)

We used similar methods to model risk of agricultural development (slide #10). We used models developed by Burris and Skagen (2012) to understand playa loss due to climate change (slide #11 shows predicted playa availability by 2040).

<u>FINDINGS</u>

We put these assessments together to evaluate risk of playa wetland loss based on various assumptions of wind, agricultural and climate change risk to determine conservation needs for migrating waterfowl in the region. Given these drivers, if we built out wind to meet the 2040 goal, we could potentially lose 20% of our current capacity to support waterfowl with native seeds. To avoid this scenario, we need to look at the conservation opportunities and get a commitment to action from everyone involved.

We want to avoid locating wind turbines in wetlands – including playa lakes which may be dry at the time a wind developer is assessing the area.

Looking more closely at a county in Texas, we mapped suitability for playas and playa clusters with wind resource areas. In the southern part of the county, our model shows areas with the highest suitability for wind not impacting playas; in the northern part of the county, however, areas with high wind energy suitability conflict with playas.

CONCLUSIONS / APPLICATIONS

The power of landscape design is that it allows us to understand the interactions between biological concerns and the economic needs of the region, and to develop conservation plans that acknowledge both. The results of these models are being used by PLJV and its partners to understand risk of habitat loss on the landscape, how and where to mitigate that risk, and to provide guidance to wind energy developers to focus wind development on areas that do not impact playas so much.

Questions & Discussion

Q: *How do these planning tools account for transmission availability and congestion, wind resource and other constraints on commercially viable wind development?*

Jim: Have worked with several transmission companies – use a similar assessment to show the areas that would be better for transmission lines to pass through, have worked with companies on identifying those routes. Wind resource information is identified in our assessment.

Anne: Could work with transmission to find areas that would disturb as few playas as possible.

Q: *What was the basis for the buffers used in the siting tool (distance from bat caves, etc.)? Was there a substantial body of evidence to support the buffers?*

Jim: Used references from USFWS, WAFWA, TNC and other literature. Additional information can be found in the 'Descriptive Paper' (Appendix A) on nature.org/sitewindright. Plan to update the assessment as information becomes available.

Q: *Has there been any adoption of modeling analysis by state agencies into their siting policies? What process have you begun or are considering for state or federal agencies or industry to use the tools you have developed?*

Anne: Working to develop a webserve like The Nature Conservancy has. Working with a couple of Wildlife Refuges. Models shown are basis for those discussions.

Jim: We have made FWS and state agencies in KS and OK aware of our work. It's an easily accessible source of information for a broad range of people to use. A lot of decision-making occurs at the county level in KS, commissioners and planning/zoning boards are looking for information to help them make siting decisions. We want to encourage people to contact state and federal agencies and use various forms of information, including our assessment to help make informed decisions.

Q: *Are these tools readily adaptable to other types of land use? Other layers you would use?*

Anne: Yes. Models are really just suitability models; what changes is what goals you set – if you have a goal for oil or gas development, that has to be added to the landscape planning.

Jim: Yes. Could add additional layers. In case of oil and gas, well sites, tank batteries, etc. could use our spatial tool to assist with those locations.

Questions not addressed during the session Q&A

For Anne:

Q: *You say that the thought of 5,000 waterfowl descending on those playas would give you pause. What data are available that would indicate that water birds are at significant risk of wind turbine collision?*

A: There are no data about avian collisions at wind farms located near playas. But, it is our belief that large flocks that take-off or land as a group may be at higher risk that individual birds because of the jockeying for space that occurs in large flocks. Our approach is a conservative one, in that we should do our best to avoid negative direct or indirect effects in the absence of data.

Q: *What is an appropriate setback for turbines from playas – and what is that based on?*

A: There are no data on appropriate setback distances from playas and we don't have a recommended setback. We recommend avoiding the playa clusters, based on a conservative approach that we should do our best to avoid negative direct or indirect effects in the absence of data.

Q: *Are the larger, semi-permanent saline wetland basins considered also?*

A: Yes, we recommend avoiding them as well because they are very rare (~50) and many of them no longer function (e.g., the springs that feed them have dried up and thus the wetland no longer has water).

Q: *Was there public input into the Playa Lakes Plan?*

A: No, we are not a public, regulatory agency and so we are not required to have public input. We do however, try to involve as many partners as possible that are interested in conservation in the western Great Plains.

Q: *How should developers consult with the Playa Lakes Joint Venture? How does PLJV interact with state or federal agencies that may have a regulatory or permitting role?*

A: Developers can contact us directly. In fact, we have had been contacted by wind and solar companies in the past. We are happy to provide data, answer questions, and we are interested in working on a landscape design with energy companies.

PLJV is a partnership organization and so we work closely with state and federal wildlife agencies. We have representatives from each of the six state wildlife agencies on our management board as well as representatives from US Forest Service, US Fish and Wildlife Service, Bureau of Land Management, Farm Services Agency and Natural Resources Conservation Service. PLJV itself does not have a regulatory mission, unlike our state and federal partners. On issues relating to energy development, we provide data, scientific input and review, and answer questions for our partnership.

<u>For Jim</u>:

Q: *Why did The Nature Conservancy opt to produce a map of low wildlife risk areas, rather than a map showing critical areas to avoid?*

A: The fundamental purpose of the Central Plains Low-Risk Wind tool is to facilitate wind development by identifying areas where wind energy development poses a low ecological risk and can therefore proceed with minimal conflicts. We used the low-risk development area approach (as opposed to identifying areas that should be off limits) in hopes it would encourage and facilitate more development of emission-free energy while avoiding potential business and ecological pitfalls. Controversial projects with negative ecological impacts can slow these projects or jeopardize the development of future projects, something that none of us want to see. At its core, the product is intended to advance wind energy development.

Q: *How is this tool different from USFWS's Information for Planning and Conservation (IPAC) tool?*

A: The Fish & Wildlife Service tool offers general guidance and data for siting; our tool provides more specific information for the targeted region.

Q: *What responses have you received from the wind industry? Did TNC solicit input from the industry before making this tool public?*

A: We have received feedback from both developers and wind energy purchasers, though primarily from power purchasers. The responses have been strongly positive. As we continue to meet with power purchasers, developers, and others, we will seek additional input regarding opportunities to improve the tool.

Q: Is there a plan to add a "site oil and gas right" module?

A: Working with all industries that can have unintended negative impacts on wildlife and their habitat is crucial to conservation success, and these efforts have included working directly with the oil and gas industry. For instance, the Conservancy has developed a siting tool for shale oil and gas development in the Appalachians.

Q: *Given that TNC has no regulatory authority, how do you plan to permanently protect your priority lands from any other form of development in the event wind developers agreed to avoid them? We believe that a market-based approach is superior to regulation; that the wind energy industry itself, given accurate information, offers a better long-term solution than does regulatory action.*

A: We too believe that a market-based approach is appropriate. That is why we are making the tool available to all stakeholders in the wind energy market (developers, purchasers, financiers, regulators, the public, etc.), to educate them about ecological factors related to wind energy development. This allows all of the players in the market to decide what is important to them when making their decisions as part of this wind energy deployment process. Educated

stakeholders will make better decisions. This fact points to the need for broad collaboration, especially in the absence of regulations or rules for siting renewable energy.

Q: *How does a developer who chooses to use this mapping tool compete with developers who choose to ignore this map with no penalty or risk?*

The stakeholders who utilize this approach will ultimately make it difficult for those who would site projects irresponsibly. A key to this approach is rapidly educating as many players as possible across the renewable energy spectrum, including those that have traditionally not been a part of these important conversations, such as the power purchasers. This business pressure, we believe, will be sufficient to create parity in competition and favor those who do site projects responsibly.

Q: *What about private land – how do you tell landowners that resources on their properties preclude them from having a profitable wind energy development (or any other type of development)?*

The landscape is covered with various types of development restrictions – state laws, county-level zoning, geological and hydrological barriers, other forms of development, etc. We are not telling private landowners or developers what they can or cannot do. Rather, we are identifying areas, based on the best available science, where there appear to be fewer ecological risks for wind development. We are simply making existing information more readily available.

Q: What effect would wind development have on American burying beetles (ABB)?

The ABB is federally listed as endangered under the Endangered Species Act. Like many other construction projects, the impacts related to wind energy facility development may cause direct mortality, which will necessitate coordination with the USFWS. Consequently, we chose to avoid ABB priority conservation area polygons within the low-risk development areas.

Q: *Did you consider other parts of the eagle's annual life cycle, i.e. overwintering habitat?*

A: Yes, we are currently determining a means to fairly capture and represent these areas. We may add additional information in a later iteration if more clarity or information becomes available.

Q: *Kansas has a bag limit of two greater prairie chickens per day during the hunting season (mid-November through January). If the state sanctions recreational killing of these birds, is it reasonable to ask wind developers to avoid their habitat?*

A: Our low-risk development area approach is a tool designed to help minimize risks for developers, purchasers, and other stakeholders in the wind energy market. Based on long-term data sets, hunting has not been found to impact the species at a population level (as opposed to permanent development within core habitat).

In Conclusion

The Conservancy's wind siting tool attempts to look at the big picture when it comes to prairie grouse and other affected species by addressing cumulative impacts to the species and its habitat, which can have long term negative consequences on populations. While a single poorly-sited project may not cause the demise of a species, the combined impacts across many projects of various types is having a negative effect on species populations. Looking only at project level impacts risks further chipping away at what little intact native habitat remains.

We believe that responsible stakeholders in the wind energy market will want to avoid causing negative impacts to ecological resources while they are promoting, developing, and using renewable wind energy. Many companies now have sustainability principles that encourage the consideration of all impacts of their business decisions and practices. But the choice is theirs to make; the information in the Conservancy's wind siting tool is intended to help facilitate informed decisions in this regard, if stakeholders are interested in doing that.

Offshore Wind Energy

Moderator: Kate Williams, Biodiversity Research Institute

Exploring the Displacement of Seabirds
from Offshore Wind Farms (OWFs)

Presenter: Fraser Carter, Joint Nature Conservation Committee

Author: Fraser Carter (Joint Nature Conservation Committee)

PROBLEM / RESEARCH NEED

The development of offshore wind farms is rapidly growing worldwide, with 91% of that development taking place in Europe. Europe's offshore wind energy production more than doubled its capacity between 2014 and 2015, reaching 11 GW in 2015. Seventy percent of this capacity is sited in the North Sea, and much of that in U.K. waters. Along with added capacity, the average size of offshore wind farms and the number of potential siting locations have increased. All of this contributes to a changing marine environment.

Many planned and existing wind farm installations coincide with important foraging areas for breeding, wintering and migrating marine birds. This interaction poses a number of potential threats to marine birds. Collisions are the first thing we think of, but avoidance also raises issues: micro-avoidance within a wind farm, and macro avoidance which can lead to displacement from large areas.

Gaining an understanding of displacement and potential consequences to the population is vital in order to assess the cumulative effects of multiple wind farms. This is particularly pressing given that global marine bird populations have declined dramatically over the past half a century. It may be of particular interest to wind farm developers as the legal requirement to protect birds under the Birds Directive can delay or even prevent wind farm construction.

APPROACH

The effects of displacement are difficult to measure and understand. Displacement effects have the potential to impact populations in several ways, including exclusion from important foraging areas and increasing competition for resources. Birds may have to travel farther, increasing energy expenditure and spending more time away from their nests. This could have

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ripple effects on the wider population. Displacement may therefore be seen as functional habitat loss.

An increasing number of monitoring studies are beginning to improve our understanding of displacement effects, but empirical evidence of species-specific reactions to wind farms, displacement rates, and the fate of birds displaced from offshore wind farms is still limited. There remains significant uncertainty surrounding the potential population consequences that displaced birds face.

FINDINGS

We are beginning to better understand which species are being displaced and species-specific avoidance patterns. It is more difficult to work out the consequences. Many factors influence bird abundance and distribution. Creating a matrix that multiplies the proportion of population displaced and the consequence of displacement in terms of mortality level is one way to assess the larger consequences for a population.

Distribution surveys don't let us distinguish local changes from wider regional ones. This uncertainty results in knowledge gaps which leads to precaution in displacement assessments. Displacement may be more of a problem for less adaptive species and more constrained individuals (e.g., breeding/nesting birds). The red-throated diver, for example, has very specific foraging habitat requirements. Evidence of displacement of this protected bird essentially "pulled the plug" on Phase 2 of the London Array Offshore Wind Farm, located off the coast of South East England. Highly mobile species are also vulnerable to cumulative impacts as the number of OWFs multiplies.

About 500 other species are afforded protection under the Birds Directive, which aims to protect and conserve wild bird species across Europe. The classification of Special Protection Areas is one conservation mechanism, but the scale of potential effects of displacement on marine bird populations is still largely unknown.

CONCLUSIONS / FUTURE DIRECTIONS

There are several projects underway in the U.K. that are aimed at filling critical knowledge gaps:
- What is the fate of displaced birds?
- Developing standard methods and metrics to guide displacement assessment
- Mapping the non-breeding season movements of vulnerable species

Collaboration is needed to help fill additional gaps in our understanding:
- Habitat use during the winter
- Connectivity between foraging/resting sites
- Identify origin of birds to establish which populations are being impacted

Responses of Marine Top Predators to an Offshore Wind Farm in UK Waters: Does Evidence Exist for Displacement?

Presenter: Nancy McLean, Natural Power

Authors: Gillian Vallejo, Kate Grellier, Emily Nelson, Ross McGregor, Nancy McLean *(Natural Power)*

<u>PROBLEM / RESEARCH NEED</u>

The number of offshore wind farms (OWFs) is rapidly increasing as they constitute a significant component of global renewable energy strategies. Deployment of the technology within U.K. waters contributes a significant, and growing, component of the U.K. renewable energy generation. There are currently over 3 GW in the U.K. permitting system, 13.5 GW awaiting construction and 6 GW either under construction or operational. This has given the U.K. legislators the opportunity to impose upon developers post permit-award monitoring requirements aimed at providing scientific evidence to the degree of impact experienced by the marine ecological receptors from offshore wind deployment.

A key concern expressed during the permitting phase of a project is displacement of marine top predators from important habitat during offshore wind farm construction and operation. The extent of displacement will vary according to species and specific stimuli. As discussed in Fraser Carter's presentation, complete avoidance of the OWF effectively constitutes loss of habitat, which may in turn impact individual survival and future productivity. Site- and species-specific monitoring in North Sea suggest that initially displaced individuals may return, but there are few long-term studies to examine such effects across taxa.

<u>Objectives</u>

We present the first cross-taxon evidence for no significant long-term displacement from a U.K. offshore wind farm for two broadly-distributed species of conservation concern : common murre (*Uria aalge*) and harbour porpoise (*Phocoena phocoena*) – both of which are known to avoid anthropogenic activity.

<u>APPROACH</u>

We analyzed abundance and distribution data for two marine top predators, common murre and harbor porpoises, from over 10 years monitoring at Robin Rigg, an OWF on the west coast of Scotland. Specifically, we sought to:

- Quantitatively compare changes in abundance and distribution across phases

- Model spatial distribution of individual observations per km

Located in the Solway Firth, Robin Rigg comprises 60 turbines and covers 13 square km. Baseline surveys were conducted in 2001-2002. An environmental management plan was a condition of the project permit obtained in March 2003, but construction did not start until late 2007, and the facility did not begin operation until April 2010, leaving a large gap between the collection of baseline data to construction and operation.

We have operational post-construction data from 2010 to the present. Data were collected during boat-based line transect surveys across a 360 square km study area that included the Robin Rigg OWF. Surveys were conducted over ten years across the pre-construction, construction and operational phases of the development. We estimated changes in common murre and harbor porpoise abundance and distribution in response to wind farm construction and operation, using generalized mixed models to test for evidence of displacement. Over the period that spanned baseline characterization to post construction, occasional benthos and fish surveys were also undertaken. Although not designed to monitor changes or account for changes in distribution of birds and fish, these surveys do provide evidence of the highly mobile, estuarine environment in which the Robin Rigg offshore wind farm is located.

FINDINGS

Both common murre and harbor porpoise were present across the study area throughout all three development phases, providing evidence for no wide-scale displacement of the estuary during construction and operation. Both common murre and harbour porpoise showed significant, local scale density distribution changes across the survey area that appeared to be independent of the presence of the offshore wind farm.

We were surprised to see any harbor porpoises within the estuary during construction. While there was a significant reduction in harbor porpoise within the Robin Rigg footprint during construction, it is likely that animals utilized the site during periods when no piling and so significant underwater noise production occurred. Numbers returned to pre-construction levels during operation. (Harbor porpoise are only visible 20% of the time under optimal weather conditions as they spend a lot of time underwater, so we had to account for large percentage of zero observations within our modeling process.)

Common murre abundance remained similar across all development phases, showing preferential habitat within the Solway Firth. However, there were significant changes in the distribution of murres within the estuary as a whole, probably due to a shifting of preferred habitat in the form of moving sand banks.

CONCLUSIONS / APPLICATIONS

This is the first cross-taxon evidence for no significant long-term displacement from an offshore wind farm in U.K. waters. The results of these surveys suggest that:

- storm and tide-related sediment movement – unrelated to offshore wind farm presence – is responsible for changes in prey species distribution; and that

- local prey availability is likely to be more important in determining the abundance and distribution of marine top predators than perturbations associated with offshore wind farm construction and operation.

This extensive dataset adds to existing evidence base from North Sea, with the empirical data indicating, at most, low levels of temporary displacement from OWFs. More general take-away lessons from this study:

- Consideration of prey availability is important in understanding the context of potential OWF impacts.

- Involve scientists in development of pre-, during and post-construction survey methodology to detect and determine reasons for change/no change in distributions of focal species.

Questions & Discussion (*Nancy McLean & Fraser Carter presentations*)

Q: *How many years for pre- and post-construction surveys that you would recommend? How many surveys per year are needed for good statistical analysis? If you could go back to the beginning of your work, what baseline survey methods would you have used to better understand displacement effects?*

Nancy: It would have been helpful to get some guidance from the statutory entities – see poster on survey design. These surveys were designed to establish baseline conditions – such surveys are usually not robust enough to significantly detect displacement. We had to undertake modeling to get the distribution info we needed to detect change. In addition, methodologies have changed a lot in 12 years. We now use larger vessels with higher viewing platforms so you can see over the swells, but survey methodology had to remain the same to enable comparison between the project phases. And importantly, one survey design for one species will usually not be sufficient to detect change in another.

An important caveat to these surveys is that they provided evidence to the degree (or not) of displacement arising from the construction and operation activities of the wind farm. They did not provide any evidence to the effects of this potential displacement. This would require analysis of potential changes in population parameters of displacement population, not simply a binary displacement / no displacement analysis.

Q: *Is there any evidence of attraction effects at offshore wind facilities for any seabird species?*

Fraser: Yes, certain species show attraction, such as large gull species. Also cormorants and other birds that perch on turbine structures (railings on platforms?) to dry their wings.

Q: *How do we take the knowledge base we have on displacement and move toward understanding if energetic impacts of avoidance are detrimental to a populations? (For example, whether a reduction in physiological condition is impacting reproductive success or migratory abilities.)*

Nancy: Really hard to do that. For Robin Rigg, for example, even if there was displacement from the wind facility (which there did not appear to be), how could you attribute any changes at the population level to the wind farm, when so much else is changing the environment at the same time: sediment, food resources, other development, etc.

Fraser: It's tricky to work out what's actually happening to birds that are displaced, what are the energetics effects.

Alicia: BOEM always asked: how do you tell if there are population impacts if you don't know what the population of birds are out there? Very little known about population of Atlantic sea birds.

Nancy: Within the UK context, we have an idea of some of the bird numbers and population parameters – whether growing, stable or declining – but even so, when you have multiple factors changing, there is uncertainty around each of those parameters, and that compounds the uncertainty about population impacts.

Fraser: It's one thing to look at a population of birds during, say, the breeding season, where you have a colony of birds and you can look at what's going on within that colony. But during the non-breeding season, populations are more dispersed, and trying to tie individual impacts back to the colony and to a population is a lot more difficult.

Kate Williams: trying to figure out what displacement means in terms of survival or reproductive success is very tricky.

<u>Nancy/ Fraser - Additional Questions not Addressed during the Session</u>

Q [Fraser]: *What is a "bow and arrow" post-construction survey? What other survey methods can be used to assess fatalities at offshore wind facilities?*

A: Not "bow and arrow" but *"boat and aerial"* post-construction survey. This method uses boats and/or aircraft to undertake surveys of bird abundance and distribution at wind farm development sites once the wind farm has been built.

Trying to survey and assess fatalities at offshore wind farms is inherently difficult. The clues that help us to identify impacts are unlikely to stick around. For example, unlike terrestrial wind farms where some carcasses may stay on site and allow quantification of mortality, any birds that are victims of collision offshore are likely to be washed away. Determining the fatality caused by displacement may be even harder as many of the consequences are indirect. However, current work in the UK is looking to understand the fate of displaced birds. This in turn may help us to better assess the impact of offshore wind farms on birds.

Q [Nancy]: *How do we move from relatively static assessment of marine animals to incorporate what we expect will change as climate changes – for example, as seas surface temperature fronts shift location into the future? How do we incorporate this challenge into siting facilities?*

A: I think that this is one of the aims of incorporation of the 'ecosystem services' approach being advocated at the impact assessment stage. Baseline would describe where the surface temperature fronts are presently located, and thus where cold and warm water mix to provide nutrient rich waters and thus food chain hot-spots. Impact assessment would then have to predict where (and if) these front may move, and impacts this would have on the food chain and thus distribution of key predators. This would enable a 'do nothing' scenario for a baseline, over which one could impose a CO_2 reduction scenario if global targets are met.

However, current degrees of uncertainty and differing of opinion of experts currently involved in trying to model impacts and effects of offshore wind increase the complexity and thus limit confidence in the outputs of modelling exercises. Adding further uncertainty and complexity at this stage in the development of the assessment process may be counterproductive at this point in time.

Q [Nancy]: *Please comment on the use of design envelopes to minimize bird impacts at offshore wind farms in Europe.*

A: There are a couple of examples for how Design Envelopes have been used in this way within a UK context. Current Design Envelopes are likely to include turbine technology from the 6 MW to the 12 MW+ class. Thus to reach a desired capacity (or project output) there will be range in turbine numbers that could be deployed – either a larger number of smaller machines or a smaller number of larger machines. Studies have shown that aviation collision risk is directly related to the time a bird spends within the rotor swept area of the turbines, and thus for offshore birds in the height bands of 25 m+ above sea level. Such flight activity is typically limited to heights of between 25 and 60 m, while most flights occur below this height, outside of collision risk. The volume of air within the swept area that poses this collision risk to seabirds is not equal for any given wind farm capacity. For example, the swept area within this height band for one 12 MW turbine is likely to be smaller than two 6 MW turbines. Thus larger machines can mitigate collision risk, and thus mortality, if there are a large number of birds flying at rotor swept height within a wind farm site.

Similar considerations can be applied to hub heights of turbines. For any given rotor size (and thus capacity), the collision risk will be dependent upon the height of 'blade free' air between the sea surface and the lowest reach of the turbine blade. Raising a hub height for any given turbine will increase the height of this collision risk free volume, and thus reduce collision risk overall. The cost of raising a hub height in this manner is expensive in foundation design and construction, as well as extra steel for turbine towers. But it can be considered if such mitigation is required.

Q [Nancy]: *Do your maps of displacement within the wind project present evidence of risk to the species or evidence of successful adaptation to the wind project?*

A: I think that the maps presented illustrate that the drivers for species distribution are complex and that animals are probably more responsive to food source distribution and preferential habitat than presence of the wind farm itself. We have evidence from the UK as to the adaptation of species to the infrastructure of the wind farm. But ultimately, I think that if the habitat and food source are attractive, animals will tolerate the wind farm. If the habitat and food source are less attractive, then there is less reason adapt and displacement may be detected (if the animals were present in the first place).

Q [Nancy]: *How did you separate wind farm impacts from natural variability?*

A: We didn't/couldn't separate impacts from the surveys that were undertaken. That would have required dedicated surveys designed to robustly detect change, and the reasons for change, rather than a repetition of baseline surveys as conducted here.

Collision and Displacement Vulnerability among Marine Birds of the California Current System Associated with Offshore Wind Energy Infrastructure

Presenter: Emma C. Kelsey, U.S. Geological Survey

Authors: Emma C. Kelsey, Josh Adams, Jonathan Felis (*USGS*), David Pereksta (*BOEM*)

PROBLEM / RESEARCH NEED

Characterized by open areas with persistent winds, the offshore environment has the wind energy development potential to produce a significant proportion of the power necessary to reach the United States' alternative energy needs. The California Current System (CCS) is a nutrient-rich zone. Given offshore topography – the 200 m continental shelf is very close to shore – most of turbine development being considered is of a floating turbine type. Marine species already face threats from species by-catch, plastic debris, and other anthropogenic-driven changes. The development of offshore wind energy infrastructure poses collision risk and displacement. The purpose of this study was to assess species-specific risk in the hopes of informing offshore wind energy facility siting and management decisions.

Objectives

Our objective was to create a comprehensive database of marine bird vulnerability to offshore wind energy development in the California Current System (CCS), made accessible in the form of an open file report from USGS. This is the first offshore assessment done for the western United States, based on studies in the North Sea.

APPROACH

We referenced previous vulnerability indices from European North Sea and U.S. Atlantic studies, and gathered Seabird Survey records for each of the 62 seabird and 19 marine water bird species that occur in the CCS. Using published values on population size, demography, life history, flight heights, and avoidance behavior for these species, we generated three vulnerability indices.

- Collision Vulnerability – based on:
    - Diurnal and nocturnal flight activity
    - Time flying in rotor sweep zone
    - Macro-avoidance

- Displacement Vulnerability – based on:
    - Macro-avoidance
    - Habitat flexibility

- Population Vulnerability – based on:
    - Global population size
    - Percent of population in CCS
    - Annual occurrence
    - Threat ranking
    - Adult survival
    - Breeding score

Vulnerability values for each species were determined on the basis of a comprehensive literature review (over 200 sources) and expert opinion, with uncertainty range bracketing each metric value used. Population vulnerability was used as a scaling factor to collision and displacement vulnerability to generate two comprehensive indices:

- Population Collision Vulnerability (PCV)
- Population Displacement Vulnerability (PDV).

FINDINGS

Pelicans, terns, gulls, cormorants, and ashy storm-petrel had the greatest PCV scores. Brown pelican (*Pelicanus occidentalis*) had the greatest overall PCV score, due to their high population vulnerability and a flight behavior that makes them at risk for potential collisions. Alcids, terns, loons, and ashy storm-petrel had the greatest PDV scores. Ashy storm-petrel (*Oceanodroma homochroa*) had the greatest overall PDV score because it is endemic to the CCS, which means that it is highly vulnerable on a population level, and because it is sensitive to disturbance.

Using at-sea survey data, we also mapped bird densities within the CCS as a function of their cumulative PCV and PDV scores. This spatial analysis indicated areas in the CCS where seabirds would be more vulnerable to collision with and displacement by offshore wind energy development.

CONCLUSIONS / APPLICATIONS

The vulnerability assessment presented here can be applied to specific locations in the CCS where offshore wind is being considered and can be used to help inform decisions that will impact seabird conservation.

For example, for a Morro Bay offshore lease request, we mapped species distributions and calculated densities (per 5' x 5' grid cells), then applied vulnerability scores on a common scale. For each survey, the quantile rank of species densities for each 5' grid cell was determined, multiplied by the percentage rank of PCV and PDV scores, and summed for all species. We then overlayed this with the area requested for 100 floating turbines about 30 miles offshore. The lease requests correspond with areas of moderate vulnerability, but we can also focus on which species' scores are driving the vulnerability in those sites, in order to look at what mitigation might be possible.

We want to do same spatial analysis for entire CCS, and also add temporal (seasonal) data. We hope that this will inform management decisions, and that quantifying uncertainty around vulnerability scores will help us to focus future research. We plan to do a similar assessment for Hawaii.

Questions & Discussion

Q: *Could you go into a bit more detail about how displacement vulnerability score was calculated?*

A: Displacement Vulnerability was based on scores of macro-avoidance rate and habitat flexibility. Macro avoidance scores were based on macro-avoidance rates published for species avoidance of wind farms in the North Sea. When macro-avoidance rates weren't available for the California Current species in question, we used macro avoidance rates from similar species. In these cases, the uncertainty levels around the score was higher. Habitat flexibility score was based on whether species was an opportunistic or specific forager, a species that is an opportunistic forager would have greater habitat flexibility.

Q: *Will USGS' vulnerability assessment incorporate data from existing and future wind farms to test validity, and if so, how?*

A: Not yet. The Pacific coast still in the very beginning stages of lease process for potential development, so it will be a long way out before we could compare our vulnerability assessment with actual impacts. Re-evaluations have been done on original vulnerability assessments in the North Sea, and I hope that we will be able to do the same in the future.

Q: *In calculating vulnerability, are you considering the effects of habitat created by platforms, which may attract fish and thus attract foraging birds?*

A: As best we could we took attraction into account in coming up with macro-avoidance scores (negative avoidance equals attraction).

Additional question not addressed during Q&A session:

Q: *In your graph of vulnerability to collision and to displacement, is it proper to assume that a species falling on the one-to-one line has equal population risk from each cause?*

A: I'm not sure I understand the question but population vulnerability was calculated independently for each species. Then the population vulnerability score was multiplied by the collision vulnerability and displacement vulnerability score for each species. So yes, each species had an equal population vulnerability score contributing to the final population collision vulnerability vs. population displacement vulnerability graph.

Satellite Tracking Highlights Use of Ocean Habitat by Diving Bird Species in Federal Waters of the US Mid-Atlantic

Presenter: Alicia Berlin, U.S. Geological Survey Patuxent Wildlife Research Center

Authors: Alicia Berlin (USGS Patuxent Wildlife Research Center), Scott Ford (Brook-Falls Veterinary Hospital), Andrew Gilbert (Biodiversity Research Institute), Carrie Gray (Biodiversity Research Institute), Scott Johnston (U.S. Fish and Wildlife Service), William Montevecchi (Memorial University of Newfoundland), Glenn Olsen (USGS Patuxent Wildlife Research Center), Lucas Savoy (Biodiversity Research Institute), Caleb Spiegel (U.S. Fish and Wildlife Service), Iain Stenhouse (Biodiversity Research Institute)

PROBLEM / RESEARCH NEED

Offshore wind energy is one of the fastest-growing sectors of world energy development, offering a clean abundant source of electricity to meet demands. Offshore wind facilities may however impact many bird species, exposing them to increased mortality through turbine collisions and by altering behavior and flight pathways. Several wind energy facilities are currently being planned for offshore U.S. Atlantic waters. To evaluate the potential for effects on marine birds posed by wind turbines in Federal waters (>5.6 km from shore), there is a need to collect information on the distribution, seasonal occupancy and behavior (e.g., flight pathways timing, etc.) of a broad suite of birds in these areas.

<u>Objectives</u>

Evaluate the fine-scale occurrence and movement patterns of three diving bird species with different flight and foraging characteristics in the near-coastal federal waters of the U.S. mid-Atlantic area (North Carolina to Long Island, New York). We focused on wintering and migration to and from the mid-Atlantic for three species representative of species groups – Red-throated Loons, Surf Scoters, and Northern Gannets. All three winter in the mid-Atlantic, but exhibit different foraging behaviors.

<u>APPROACH</u>

This was a large collaborative project involving five different agencies over a four-year period.

From 2012-2016, we tracked the movements of Northern Gannets (n=75) and Red-throated Loons (n=66), and from 2011-2016, Surf Scoters (n=217) in mid-Atlantic waters, on their northward migration to their breeding colonies, and on their southward migration back to and through the mid-Atlantic region. Different age classes of gannets from colonies in both major breeding areas (Gulf of St. Lawrence and eastern Newfoundland) use estuarine, bay, coastal, and pelagic habitats during winter, and the mid-Atlantic region and the Gulf of Mexico are hotspots for Northern Gannets during winter.

Birds were captured and tagged from 2012 to 2015 in the Delaware and Chesapeake Bays, Pamlico Sound, Cape St. Mary's (gannets). The goal was to put out 20 tags on each species each year, so totaling 80 tags per species over four years. Additional surf scoter data provided by a parallel collaborative study supported by the Sea Duck Joint Venture and numerous other partners were incorporated to increase sample sizes for both projects and provide analyses on potential capture biases. Birds were banded and measured, and appropriately sized birds were tagged using surgically implanted transmitters (tail tapes were used on a total of 15 birds captured in 2012. Birds were then released close to their capture sites.

A highly automated process was used to download, compile and filter data. Early post-surgery data was removed (as well as for animals that did not survive at least 30 days post-surgery). Bird movements were delineated manually for breeding, wintering, etc., allowing us to analyze movements within specific periods. Dynamic Brownian bridge models seem to do the best job at describing the individual use of the area. We reasoned that by pooling lots of individual surfaces into one mean surface, we would eventually arrive at the population level utilization distribution.

<u>FINDINGS</u>

We split out exposure for each species by season (spring, fall, winter). For Gannets, the entire Atlantic coast is important year round. Loons and scoters use the offshore environment during spring migration.

Breeding ranges

We came up with one map showing the distribution of breeding ranges for each of the three species. Loons went all the way up into the Arctic Circle for breeding.

Winter composite utilization distributions

For loons, concentration on the bays could be confounded by fact that the captures took place primarily in the bays. Analyses on how utilization distributions compare for scoters captured in the mid-Atlantic with scoters captured in the St. Lawrence are underway.

Fall migration

During the return fall migration, both colony and winter-caught gannets move from shelf to coastal waters, as they travel to or pass through the mid-Atlantic region on their way to the South Atlantic Bight or Gulf of Mexico. The use of coastal waters appears to be more pronounced among females. Red-throated Loons' winter use near potential wind energy lease areas was greatest along the western edge of the North Carolina wind-planning area off the Outer Banks; spring and fall migration movements also overlapped with that area. Migration trajectories through New Jersey and Delaware lease blocks were heavier during the spring than fall.

In general, the greatest chance for interaction between Red-throated Loons and potential wind energy areas occurred during the migration periods rather than winter. Kernel density estimations for both sexes of Surf Scoters showed that core-use areas during the wintering period encompassed the majority of both Chesapeake Bay and Delaware Bay, with additional smaller core-use areas occurring south of Cape Cod near Nantucket Shoals, in Long Island Sound, and in Pamlico Sound, NC. During migration scoters followed a route within 18.5 km of the Atlantic coastline to staging areas near the Gulf of St. Lawrence. They therefore may not be influenced by the proposed wind energy areas controlled under Bureau of Ocean and Energy Management (BOEM) jurisdiction, but state plans may impact this species.

Our final report is due in May. We are now doing second and third order habitat analysis to see what factors (distance to shore, water depth, bathymetry, etc.) influence exposure.

CONCLUSIONS / APPLICATIONS

These data are designed to inform permitting and regulation of future offshore wind development in the Atlantic region and provide important information on key habitat use and migration of a suite of species with different ecological niches. Our preliminary findings indicate heavy use of bays – though this may be an artifact of where birds were captured – with offshore use varying by season and species. A researcher has found different movements for juveniles, so we will want to look more at age differences for all species.

Questions & Discussion

Q: *Will you be comparing your distribution results to those from other survey efforts? In particular, can you use satellite telemetry results in conjunction with your survey data?*

A: This has come up repeatedly. Unfortunately, they are very different types of data, different resolution. We are working with people who are looking at survey data of all birds up and down the coast, but have yet to combine survey data together with telemetry data.

Q: *What was the tagging success rate?*

A: It varied by species. Gannets did very well (larger bird relative to size of transmitter). Loons not as well potentially due to stress related to handling. Other birds, such as scoters, had lower incidences of mortality. Mortality dropped when we started using a mild sedative (Midazolam) as soon as the loons were caught, but the same drug adversely effected gannets. Further efforts into reducing handling time and thus is needed but no one technique works for all species.

Additional question not addressed during the session Q&A:

Q: *How can we directly use this data? Did you identify specific timeframes of high use that can be avoided during construction to minimize risk?*

A: The seasonal composites of utilized distributions of species give an excellent representation of spatial use of our sample: i.e., if and when birds were exposed to current Offshore Lease and Wind Energy Areas (WEA). However it is inappropriate to interpret these maps as representative of the population as a whole; we were unable to fully control for potential capture bias, and large portions of the overall population (i.e., juveniles) were not tagged as part of this study.

Examining individual movement data to infer specific conditions or times of 'high risk' is also difficult due to the coarse timeframe sampling occurred. Thus, it is often impossible to know if an individual crossing a Lease/WEA spent one hour, or 24+ hours within an area where it may have been exposed to direct conflict with a turbine. We also do not yet have a grasp of the altitude/behavioral activities that characterize these transits, a big component in evaluating exposure risk.

Bats at Sea: A Final 6-Year Summary of Bat Monitoring on Islands, Offshore Structures, and Coastal Sites in the Gulf of Maine, Mid-Atlantic States, and Great Lakes Regions

Presenter: Steve Pelletier, Stantec Consulting Services, Inc.

Authors: Steve Pelletier (Stantec Consulting Services Inc.), Trevor Peterson (Stantec Consulting Services Inc.)

PROBLEM / RESEARCH NEED

The largest coordinated effort to monitor offshore bat activity in North America occurred in the Gulf of Maine, Great Lakes, and mid-Atlantic coastal regions between 2009 and 2015. In 2009 we initiated an internal pilot study investigating presence/absence of bats offshore in which we deployed paired acoustic detectors at 12 coastal and island locations off the ME coast. The fact both migratory and non-migratory bats were found at each of the 12 locations during the first year prompted an expansion of the study over the next 2 years, again leading to similar observations, and ultimately a 3-year extension into the mid-Atlantic coastal states and Great Lakes regions, with support from the DOE.

That work is now complete resulting in an extensive collection of temporal and spatial data that's helped better define patterns of offshore bat use within these three regions.

Objectives

This study aimed to document seasonal and spatial patterns in bat presence offshore and to ultimately improve our understanding of potential risks associated with offshore wind energy development. Our purpose was to determine if bats were using offshore areas, and if so, to what extent, and if individual species patterns might be similar to trends being observed using similar techniques at projects in terrestrial settings within the northeast.

APPROACH

Two preliminary questions had to do with methods and deployment:

- Could acoustic technology and equipment being routinely deployed on land also be reliably used to document long-term bat activity in a remote, extremely harsh, marine environment?

- Where or how best to deploy that equipment?

We deployed passive acoustic bat detectors at 41 sites that were segregated into 6 categories, including seven coastal locations, nine large islands (defined here as >200 ha), eight medium and six small islands (at <15 ha), eight offshore structures, and aboard three NOAA research vessels. We monitored a total of 24 sites in the Gulf of Maine, in some places getting six years of data. Seven sites were surveyed on Lake Superior and Lake Erie, along with eight sites along the Mid-Atlantic coastal region, for two to three years. Lighthouses were frequent and effective places to mount acoustic detectors, but we also used a series of offshore structures and boats as well, recording calls an average of 37 miles from shore.

The use of paired and armored solar-powered detectors enabled the collection of date- and time-stamped call data, that could be directly linked to individual species or guilds, and as well to seasonal and meteorological data sets. We relied primarily on Anabat SD1 and SD2 detectors, but also included early generation Wildlife Acoustics units in several settings.

We surveyed bat activity during 16,761 detector nights across the study, recording a total of 538,248 bat passes and detecting bats at every site we monitored.

FINDINGS

Here we summarize our final results of the multi-year surveys, highlighting site-specific results that exemplify bat activity across a variety of surveyed sites, and include results of regional statistical analyses of the influence of weather variables, season, and site isolation on detection rates and presence of bats overall and by species.

The 2009 pilot study found both migratory and non-migratory bats offshore (see https://tethys.pnnl.gov/sites).

Not surprisingly, the highest bat activity levels occurred at coastal sites and some of the larger, near shore islands, but bats were observed each year at even the most remote islands and buoys. There were also pronounced seasonal trends, many not unlike those observed in similar studies in terrestrial settings. Most activity (86% of passes) occurred during the July 15 to October 15 time period, with as many as 543 passes on a single night at a site. The level of activity varied largely according to seasonal and weather related conditions.

Eastern red bats were the most widespread species occurring at 97% of sites and accounting for 40% of overall passes. They were also the most commonly identified species at offshore structures, comprising 90% of passes that were identified to species. Silver-haired and Hoary bats accounted for many fewer calls, but at 89% to 95% of the sites. Members of the *Myotis* genus were the most frequently detected species group, representing 43% of all identified bat passes – though only nine of all the passes identified from the mid-Atlantic region.

Although *Myotis* were most numerous at sites on or near the coast, they were also detected at the most remote sites. The six-year survey period in the Gulf of Maine also provided a unique window into the effects of White Nose Syndrome (WNS), as *Myotis* were initially the most

common species throughout the region but dropped dramatically after 2011. We suspect the limited number of *Myotis* in the mid-Atlantic region is also directly related to WNS.

Eastern red bats occurred at high levels during a relatively wide range of dates between July and October; hoary bats were at their highest levels in mid-August. Silver-haired bats appeared to be more selective in terms of their time offshore, moving through regions during a narrower early September period. *Myotis* species tended to either be active throughout the season at island sites that appeared to have a resident population, or else occurred sporadically during the fall migration period.

We noted regional differences in the effects of temperature and wind speed on bat activity. Not surprisingly, most activity occurs during warmer temperature periods with low wind speeds. Any increase in nightly mean wind speed had a negative effect on bat activity. Conversely, warming temperatures had a positive effect on bat activity, particularly in the range between ~10° and ~20°C.

As on land, we expect that the offshore presence of bats infers some collision risk, though the risks are more likely to diminish the greater the isolation of the site. Offshore wind does not pose a constant year round risk to bats; rather, it varies seasonally with the highest peak in the mid-July through September periods. And, as on land, we expect that any period of bat activity – or risk – can be further narrowed to times of specific weather conditions – most notably related to warmer temperatures and lower wind speeds.

CONCLUSIONS / APPLICATIONS

We conclude that bats occur offshore on a seasonally predictable basis. Acoustic detectors can help characterize high risk conditions and in the process facilitate the development of wind energy with lower risk to bats.

Additional analyses of the dataset to be conducted in coordination with other ongoing research efforts. Key questions for further research include the following.

- Do offshore turbines pose an attraction risk?

- Do bats follow offshore bat migration routes, and can we identify them?

- Do they purposely navigate to known offshore islands during migration or forage along wrack lines or use other offshore food sources?

- What patterns of bat presence and activity might we find in other coastal and offshore regions, like the Gulf of Mexico or Pacific coast?

Supported by a broad coalition of federal, state, NGO, and academic organizations, this study provided an unprecedented opportunity to describe regional and seasonal patterns in offshore bat activity. It establishes a robust baseline for future offshore bat monitoring efforts as well as a basis for evaluating potential risks associated with the development of individual offshore projects.

Q: *Two methodological questions – define "isolated" and talk about different island size classifications you used.*

A: Isolation is admittedly difficult to categorize, especially off the coast of Maine with its highly irregular coastline and 3100+ islands of varying size and ecological character. We categorized sites as "coastal" (mainland locations), small islands (<15 hectares [ha]), medium islands (15-200 ha), large islands (>200 ha), offshore "structures" (buoys, bridges, offshore platforms lacking natural habitat), or ships. To quantify the degree of isolation, we calculated the percent land area within a 3-nm circle of each survey site based on the NOAA Medium Resolution Shoreline Data-layer (NOAA 2000) using ArcGISTM Software.

Q: *Does the placement of bat acoustic recording devices on a light source introduce as systematic bias because of bugs attracted to the light?*

A: In general no, lighthouses do not appear to attract insects because it's most frequently a revolving light source. However, the Sequin Island Light off the coast of ME has a beacon that remains on continuously, and in that instance served to attract many insects, which in turn annually resulted in the highest call activity.

Final Question for All Offshore Panelists:

Q: *Based on your experience to date, what would you recommend as a priority for research?*

Alicia: The Atlantic Marine Bird Cooperative group recently came up with two high priorities:

1) What is connectivity between wintering, migration and breeding colonies – and not just from satellite telemetry, but with really high resolution fine-scale data, wintering and movement for bird colonies.

2) How are changes in habitat and movements of fish affecting birds' foraging patterns and movements.

Steve: The threat of White Nose Syndrome is a real and population level threat to North America's Myotis and other cave dwelling species. Establishing a regional and longer term, acoustic based monitoring system like that conducted by Stantec would establish a baseline for areas not yet affected by this disease and allow decline/ recovery trends to be established and maintained.

Data collected with the implementation of a regional acoustic monitoring system as described above would similarly facilitate a more precise understanding of temporal (seasonal/ nightly) periods and (weather) conditions that – either individually or combined - pose a higher risk of collision mortality. These data would ultimately facilitate methodical development of a viable Adaptive Management program.

Separate from the expanded deployment of acoustic detectors, would be federal leadership in the coordination and expanded deployment of nanotag technology e.g., MOTUS Wildlife Tracking System http://www.birdscanada.org/research/motus/. Such a system would be mutually supported by federal, provincial/state, private partnerships that contribute site-specific, radio telemetry data over broad continental regions via deployment of low-cost receiving stations, ultimately providing a cost-effective means of monitoring an unlimited number of far ranging organisms.

Nancy: We need to try to work out why marine animals are found in certain areas, and how those are changing as a result of climate change. The baseline isn't what's there now, but what that will look in 10-15 years' time as waters warm.

Fraser: These baselines would feed into assessing cumulative impacts.

Emma: There is still so much we don't know about these species. Getting better baseline understanding of population sizes, at-sea distributions, and colony locations would be very helpful. I think that there is a lot of exciting new technology that can be applied to such studies. Tagging birds is valuable, but energy intensive and small provides a sample size.
Novel technology could provide more data collection options that we haven't yet considered.

Innovative Approaches to Fatality Monitoring

Moderator: Wally Erickson, Western EcoSystems Technology (WEST), Inc.

Challenges with the Multitude of Fatality Estimators and the Need for a Generalized Estimator

Presenter: Cris Hein, Bat Conservation International

Authors: Cris Hein (Bat Conservation International), Michael Schirmacher (Bat Conservation International), Manuela Huso (U.S. Geological Survey)

PROBLEM / RESEARCH NEED

Fatality estimation is essential for understanding impacts of any wind energy on wildlife. Estimating fatality of bats and birds at wind energy facilities is a complicated endeavor; estimators take raw data and apply several correction factors to account for biases and produce an unbiased estimate. There are about a dozen estimators, including Shoenfeld (2004), Huso et al. (2012), Korner-Nievergelt et al. (2013), and Wolpert (2013), and advances to reduce bias have been made over time. Yet the availability of multiple estimators has resulted in confusion as to which estimator is the most appropriate given certain conditions. Moreover, given the same data, different estimators can produce significantly different results. In cases where regulatory agencies require specific minimization actions to be implemented if fatality exceeds a certain threshold, the variability in results derived from multiple estimators are problematic and potentially expensive.

Objectives

To alleviate the confusion of which estimator is the most appropriate to use, we recommend the development of a generalized fatality estimator (GenEst) that allows the user to test assumptions regarding input parameters, and select the approach that best reflects their particular situation and data.

APPROACH

Case-study

In 2013, we conducted a post-construction fatality monitoring study at a wind energy facility in Pennsylvania. Fatality monitoring was conducted in accordance with the Pennsylvania Game Commission's (PGC) Wind Energy Voluntary Cooperation Agreement (Amendment 1, July 2013) Post-construction fatality data 2012–2013 were gathered using:

- 3-day searches between 1 Apr–14 July & 1 Oct–15 Nov 2013
- Daily searches between 15 Jul–30 Sep 2013
- 10 wind turbines
- 126 x 120 m square plots; 6 m transect width

The PGC Guidelines require two different estimators: Shoenfeld (which PGC refers to as Erickson) and Huso. A fatality threshold of 30 bats/turbine/year for existing facilities triggers a conversation with the PGC on how best to reduce bat fatality below the threshold. Although not specifically stated in the guidelines, the intent was to use the Shoenfeld/ Erickson estimator to evaluate the threshold.

FINDINGS

Based on a sample size of 10 turbines, the estimated number of bat fatalities was 29.22 bats/turbine (95% CI: 23.08–40.49) using the Shoenfeld/Erickson estimator, and 69.14 (95% CI: 48.77–124.65) using the Huso estimator. The 95% confidence intervals of each estimator do not contain the mean of the other, suggesting a statistically significant different between estimators. Furthermore, the Shoenfeld/Erickson estimate is below the 30 bats/turbine threshold set by the Pennsylvania Game Commission, whereas the Huso estimate is above the threshold.

The disparity among estimates are likely the result of differences in the assumptions of each estimator. For example, the Shoenfeld/Erickson estimator assumes a carcass has the same probability of being found over time (i.e., the probability of finding a carcass after multiple searches approaches 100% or k = 1). The Huso estimator assumes that a carcass missed on an initial search will not be found on subsequent searches (k = 0). This is shown to be unlikely (Korner-Nievergelt et al. 2011). The Erickson estimator assumes carcass removal occurs at a constant rate (i.e., exponential distribution), whereas the Huso estimator allows for model selection of carcass persistence based on the data. Assuming an exponential distribution rather than the best model, which in this case was a log-logistic model, resulted in an overestimation of carcass persistence and consequently an underestimate of fatality.

PROPOSED SOLUTION

Faced with a real world problem, with two different estimators yielding results on either side of the agency threshold, what to do? What estimator should others use for meta-analyses? Our proposed solution is a generalized estimator (GenEst) that takes a set of raw carcass data and the associated correction factors for biases, such as Searcher efficiency, Carcass Persistence, the probability of finding a carcass over time, and the Density-weighted Proportion of carcass distribution and uses an algorithm to determine whether your data meets the assumptions of a particular estimator.

GenEst is not intended for use in estimating rare events. It does offer the following benefits:

- ***Accommodates all assumptions and provides one estimate*** – Estimates k, replaces previous estimators, avoids confusion about which estimator is most appropriate, and allows for comparability among studies.

- ***Accurate and precise estimates for bird & bat fatality*** – allows us to understand which species are most affected and at what rate, supports effective research to avoid or minimize impacts, and facilitates compliance with permits (e.g., thresholds).

CONCLUSIONS / APPLICATIONS

Ultimately, development and use of a GenEst will:

1. Provide user-friendly guidance on study design to increase efficiency and reduce costs of fatality studies

2. Standardize carcass searches and data analyses

3. Reduce bias and thereby improve accuracy and precision of fatality estimates generated from carcass searches

A consortium of statisticians and biologists academia, NGOs, industry, consultants, agencies, and international entities make up the GenEst Working Group, which was formed in 2014. We will develop and beta test the software in 2017, and it will be made publically available along with a user's guide and beta testing. Will have final product in 2018, although, from a policy perspective, the GenEst will take some time to roll out.

Questions & Discussion

Q: *Has the GenEst been developed? And does it replace or improve upon existing estimators, take the average of their results, or simply calculate all estimators and somehow (how?) choose the best one?*

Cris: Software calculates k value and models the carcass persistence and applies it to a GenEst. Software looks for the estimator that best fits with the conditions that you have.

Paul: The four estimators can be expressed as specific forms of one generalized estimator. Once you have data, can get parameters empirically. Helps you make an assumption about what kind of k value you have and hence which is the most appropriate estimator for your situation

Q: *What does the GenEst look like and will it be available to general public as an "R" package?*

Cris/Paul: See Wolpert's appendix – software is what we're getting funding to put together.

Q: *How do the people who have been working on estimators perceive the effort to develop a generalized estimator?*

Cris: The people involved in GenEst are those same statisticians. Good collaboration.

Q: *Can different estimators serve different purposes – i.e., one is good for one situation, while another is good for another situation?*

Cris: One estimator might be more appropriate than another in a given set of conditions.

Area Correction Methods for Efficient Post-Construction Fatality Monitoring Studies

Presenter: Daniel Riser-Espinoza, Western EcoSystems Technology (WEST), Inc.

Authors: Paul Rabie (Western EcoSystems Technology, Inc.), Daniel Dalthorp (USGS), Daniel Riser-Espinoza (Western EcoSystems Technology, Inc.), Jared Studyvin (Western Ecosytems Technology, Inc.), Jerry Roppe (Avangrid Renewables)

PROBLEM / RESEARCH NEED

Post construction fatality monitoring studies at wind facilities sometimes include plots where land cover and topography present challenges to fatality searching: consider ridge tops, agricultural land that cannot be cleared, or a forested area. The solution is to restrict monitoring to areas that can be searched effectively – whether for logistical and safety reasons (e.g. rugged terrain), for improved searcher efficiency (e.g., high visibility of gravel substrate), or as a cost-saving measure (e.g. reduced crop/vegetation clearing with searches confined to existing road and turbine pad areas). Such restricted plot approaches are more efficient; surveys can be conducted more rapidly and can cover more of the facility; and visibility is easier on roads and pads. (This is a particularly efficient approach for bats, which tend to fall closer to turbines.)

The question remains: how much to monitor to adequately answer applicable Tier 4 questions? Site characteristics determine plot delineation, which in turn will determine other study design variables and hence how much effort/cost. Given more than one way to meet what the guidelines require, we want to pick the most efficient.

Objective

We present a new statistical method – weighted maximum likelihood estimation of density models for carcass distributions – to adjust fatality estimates for unsearched areas. This presentation examines the benefits of road and pad/area correction methods, introduces the latest methods being used, and discusses when such approaches are appropriate.

<u>APPROACH</u>

We compared the average plot time to search three plot types: A 100 m road-and-pad plot required 86.8% less time to search than a 90 m radius full plot, and 78.0% less time to search than a 60m radius full plot.

<u>Analytical methods</u>

Road and pad monitoring has many benefits, but making good use of this method requires appropriate analytical methods to be viable. Statistical models include:

- Logistic regression (Huso and Dalthorp 2014[1]):
    - Superimposes 1-m x 1-m grid around turbines
    - Linear or quadratic logistic regression: carcass occurrence ~ distance
    - Covariates can be included (e.g visibility class)

- Weighted distribution (WEST & USGS, in development) assumes that:
    - Carcasses that fall beneath turbine follow some known probability distribution (e.g., gamma, Weibull, half-normal).
    - Observed carcass distribution skews closer to the turbines, so adjust as a function of distance.
    - Observed distribution adjusted using detection probability weights

- Truncated Weighted Likelihood (WEST and USGS, in development):
    - Similar to weighted distribution
    - Fit the carcass distribution directly, weighted by detection probabilities as a function of distance

A preliminary comparison of these methods considers the following desirable properties: low bias, precision, correct shape, convergence, explainable and easy to use. Other desirable properties include: the ability to combine season and plot type data (a statistically rigorous way to combine season and plot type data is not yet available for the weighted distribution); allows for multiple data sources; can be generalized – asymmetry in direction.

<u>FINDINGS</u>

Preliminary results suggest that all of the above methods as well as older methods are viable, but each has its limitations and the best choice may be context-specific. Although area corrections will always add additional variability to the estimate, most of the time this should not be a big problem for most general, tier-4 type post-construction monitoring studies. These methods can be suitable when high precision is not a paramount consideration. They can be suitable for bats and birds, but note that for curtailment studies, a larger number of carcasses

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[1] Huso, M.M., Dalthorp, D., 2014, Accounting for unsearched areas in estimating wind turbine-caused fatality. DOI- 10.1002/jwmg.663: Journal of Wildlife Management, p. online.

in hand may be necessary to achieve adequate precision. Rare event monitoring does not preclude road-and-pad monitoring; however, it usually needs to be combined with some full plot sampling in order to achieve desirable probability to detect.

CONCLUSIONS / APPLICATIONS

Incompletely searched plots are a common feature of post-construction monitoring studies. They are in some cases unavoidable, and in many cases have been deemed acceptable by regulatory agencies.

We continue to test and develop these statistical methods. There is a manuscript under development testing the WEST/USGS model-based approach. Other specific directions for future research:

- More work is needed to develop bird corrections.

- We need to use new methods to look at data from a wide variety of sources and look at patterns (species, wind, turbine type, curtailment, etc.) across regions and the country.

- Anisotropic distributions may be present at a number of sites. Need to develop methods to account for directional asymmetry, not just distance from turbine.

- "Enhanced" road and pad monitoring may require two visibility classes, but this should not be difficult to incorporate. Testing is necessary to determine efficacy.

Questions & Discussion

Q: *How do road and pad searches account for incidental carcasses spotted outside the road and pad? What is the loss of precision between this method and traditional survey methods?*

Danny: We would probably exclude from model fitting, because we don't know what the search effort was. [Paul: if not in the search area, it does not get included.] There is loss of precision in the fatality estimates from incompletely searched plots because it is necessary to fit an extra model to develop the estimate.

Q: *How are you correcting for fatalities found outside your search area? How fit into your model?*

A: Ideally, just use data from one project – either road and pad, or combination of R&P and full plot. One can incorporate all those data into these models, use spatial data layers, figure out how much area they're actually searching as you move away from the turbine. And then, depending on which one of those models you use there may be other factors related to the probability of detection involved. The beauty of it is that you can have data from severely area-restricted searches and still reliably pull out the correct shape of the distribution in many cases.

Q: *You said ideally using data from individual projects; might there be cases with road-and-pad where you don't have enough data?*

A: If you want estimates for different groups (bats, small birds, large birds) – in that case, at least for the weighted likelihood method, have a pretty good idea how to incorporate data from either other projects or previous years at the same project to fit that model. With that comes some assumptions about that distribution being consistent over space and time; that's something we'll be looking into more.

Additional questions not addressed during session Q&A

Q: *Is there a limitation for R&P studies if alignment of access roads is strictly N-S or E-W?*

A: It is certainly possible in some cases, but there aren't necessarily limitations based on a regular R&P orientation. This is really a question about anisotropy, which is a topic of future research we hope to explore soon.

Q: *How would anisotropy affect your estimates?*

A: Related to the previous question, the answer is, again, it probably depends on how much area is being searched, the orientation of the area being searched, the predominant wind patterns, the type of turbine, and the species of interest and their flight characteristics. If carcass distribution is anisotropic and search areas are not equally representative with respect to direction from turbine, the resulting area adjustment will likely be biased (direction of bias may be high or low, depending on orientation of search areas).

Q: *When trying to compare multiple sites in a region, could R&P study results be easily compared with results of other post-construction fatality monitoring studies?*

A: In general yes. Ultimately, area adjustment methods will make R&P studies comparable to other R&P studies, other area restricted studies, and full plot studies.

Q: *In agricultural areas where crops are likely to cause access/visibility issues during the summer, is it better to have a larger plot size for months without crop coverage and then switch to R&P, or do only R&P year-round, knowing that you won't be able to access full-size plots during the summer months?*

A: It probably depends on the objective of the study; however, in general, the results of the area adjustment will be more precise with some full plot data.

Developing an Operations Staff-Based Monitoring Protocol for Eagle Fatalities at Wind Energy Facilities

Presenter: Paul Rabie, Western EcoSystems Technology (WEST), Inc.

Authors: Eric Hallingstad (WEST, Inc.), <u>Paul Rabie</u> (WEST, Inc.), Andrew Telander (WEST, Inc.), Wallace Erickson (WEST, Inc.), Jerry Roppe (Avangrid Renewables)

<u>PROBLEM / RESEARCH NEED</u>

Fatality monitoring has long been a primary component of post-construction surveys aimed at determining a wind energy facility's direct impacts on wildlife. Recently, additional emphasis has been placed on identifying impacts on eagle populations specifically, and mitigating those impacts when they occur. As eagle programmatic take permits are issued, permit holders will be required to conduct fatality monitoring to ensure compliance with regulatory requirements.

In most cases, two years of fatality monitoring may be needed; however, survey duration may be longer to assess the efficacy of additional conservation measures when implemented. Fatality monitoring can be a substantial expense for a facility, often costing thousands of dollars per turbine each year.

The U.S. Fish and Wildlife Service (FWS) is encouraging "creative" monitoring methods. Monthly Spill Prevention, Control, and Countermeasure (SPCC) checks require operations personnel to inspect the turbine and surrounding base area for oil spills and other contaminants. Half of all eagle detections are made incidentally, or outside of standardized surveys. These monthly SPCC inspections provide an opportunity for a cost-effective monitoring protocol using operations staff.

<u>Objectives</u>

Our objective was to develop a more cost-effective yet viable eagle fatality monitoring protocol that can be integrated into the regular maintenance routines of operations personnel at most wind energy facilities.

<u>APPROACH</u>

A robust fatality estimate requires adequate estimate of the probability of detection (g), which depends on three elements:

1. Searcher efficiency (carcass detection rates using systematic carcass searches)
2. Carcass persistence probability (Eagles and raptors in general tend to persist for a long time).
3. The proportion of carcasses occurring in a searched area

We measured searcher efficiency at three wind facilities in Washington and one wind facility in California using feathered turkey decoys as surrogates for eagle carcasses. The basic search protocol was a scan from the perimeter of the turbine pad using both naked eye (short distance) and binoculars. The searcher walked around the perimeter, stopping at four cardinal direction points. Training searchers on the search protocol is critical to the success of this approach. The search viewshed was a 150 m radius from turbine pad. Because substrate affects visibility from the pad, it is important to map and digitize surrounding substrate as easy, moderate, difficult, or unviewable. If there are unviewable or difficult areas within the viewshed, it may be desirable to walk transects through those areas to improve detection levels. This mapping is a critical as well as relatively inexpensive screening step to determine the feasibility of the approach at individual facilities.

Carcass persistence trials for both gamebirds and raptors were conducted at the three facilities in WA, and previously collected raptor persistence data from the CA site was also analyzed. All persistence times were estimated using an interval-censored modeling approach.

The probability of where a carcass will fall varies by distance from the turbine base. To determine the proportion of carcasses that would occur within the searched area, we used data from several monitoring studies to inform a distance distribution model for large raptor carcasses. We assumed that the distance distribution followed one of six probability distributions (normal, gamma, Weibull, log-logistic, Gompertz, or Rayleigh), and used AICc to select the best model for the available data.

FINDINGS

Detection rates during modified SPCC checks were generally high, with 76% of all decoys detected; however, detection was strongly dependent on habitat visibility and distance.Searcher efficiency (i.e., the estimated probability [via logistic regression] for a searcher to observe a carcass within the search area) ranged from 0.537 to 0.79. . The value at the low end of the range (0.537) corresponded to a lower visibility landscape, but may also have been a function of training at one facility.

Large raptor carcass persistence varied from 28 to 76 days. There is a clear difference in persistence between raptors and game birds that are sometimes used as surrogates in persistence trials. The probability of 30-day carcass persistence was much higher for raptors (Cooper's hawk and larger; 0.6 to 0.8) than for surrogate game birds (ring-necked pheasants and mallards; 0.2 to 0.45).

We estimate that 95% of large avian carcasses fall within 100 m of turbine bases, while 99% fall within 150 m. Using the searcher efficiency, raptor persistence, and carcass distribution estimates, and assuming a 30-day search interval, the overall probability a large avian carcass would be available and detected using the scan approach ranged from 0.50 to 0.69.

CONCLUSIONS / APPLICATIONS

We feel that the comparable searcher efficiency rates and overall probability of carcass availability and detection resulting from the scan approach offer a statistically viable monitoring method for inclusion in facility Eagle Conservation Plans. Where conditions are suitable (e.g., good visibility in areas within 150 m of turbine bases), this approach eliminates the need for the more costly, transect-based monitoring traditionally conducted at facilities.

It is less expensive by a factor of ten to use operations staff compared with 3rd party contractors conducting transect searches, and it becomes possible to survey 100% of turbines vs. 30%. There would still be external costs for establishing the operational method and training personnel, but these would still be much lower than the cost for a traditional monitoring program. Furthermore, 3rd party monitoring via the scan approach would also offer significant cost savings over transect-based searches.

We need to work with U.S. FWS to further develop and implement this approach in Eagle Conservation Plans.

Questions & Discussion

Q: *Could this approach produce statistically robust results at a facility sited in corn fields or other dense agricultural crops? How do you deal with changes in visibility in an agricultural setting over the course of the growing season?*

A: Two part answer: 1) One can get statistically robust results anywhere, but in really dense vegetation the detection probability might not be high enough to achieve monitoring goals. 2) In a case where visibility is changing rapidly through the season (e.g., a cornfield), you would have to think about defining visibility as a variable that changes through the season; it could be done but it would take a little work. It may also make sense to designate some areas unsearchable during some parts of the year and move to road-and-pad searches during those periods.

Q: *Given that eagles will be difficult to use for persistence trials, so what surrogates do you recommend?*

A: First, be aware that you need to have permits from FWS before you can use raptor carcasses in carcass removal trials, so coordination with them is required. It is probably best to contact your regional FWS office first, to see what they can tell you about raptor carcass availability. For example, FWS Region 6 is working with airports to get raptors which they may make available to wind projects for use in bias trials.

As far as which surrogates to use, large raptors would be best: *Buteo spp.* or larger. For this study we included red-tailed hawks, some turkey vultures, some owls and other raptors, too, but nothing smaller than a Cooper's hawk. Often you have to take what you can get. There have been some question about whether turkey vultures are appropriate, or may persist longer than eagles, but I'm not aware of any data to address that question.

Q: *Can you still confidently use a searchable area correction for the scan method? How are you dealing with the unsearchable areas – how are you correcting for that?*

A: The scan method has to incorporate searchable area or we can't get the probability of detection. Probability of detection combines the detection function (in this case a logistic regression) with the carcass density distribution, and the mapped searchable area. Carcass density distribution can be calculated out to an infinite horizon/distance from the turbine, and the area under that function is 1.0 (i.e. all carcasses). When you combine that curve with the searcher efficiency logistic regression and the proportion of searchable area, it automatically builds an area correction to your estimate. If there is unsearchable area within your 150 m viewshed, that will count out of your probability of detection. The carcasses that would have fallen there are automatically excluded. If you choose to go out and walk transects through those "unsearchable" areas, you can put it back in. It's bookkeeping, but you cannot fail to account for unsearched areas.

Q: *In agricultural areas where crops are likely to cause access/visibility issues during the summer months, is it better to search larger plot sizes during months without crop coverage and then switch to road and pad – or is it better to do only road and pad if that is going to be your only option during the summer?*

A: If you can consistently collect full plot data for a full season that can only help – you can switch between full plot and R&P in an orderly fashion (i.e. don't switch back and forth too frequently). If you switch very frequently it becomes difficult to account for highly variable search intervals in the off-road-and-pad areas.

Q: *Are you aware of any studies comparing carcass persistence of bat and songbird surrogates, such as mice and quail chicks? What are the preferred surrogates?*

A: When we have bats and small birds we do see a difference – bat carcasses don't persist as long as small birds. I'm not aware of any studies that address the question directly but I imagine there are publicly available PCM studies that should have those data.

Laura: Avangrid's searchers really liked having real bats rather than rodents or small birds, because the wing structure is different.

Q: *Can the Generalized Estimator work with road & pad searches as well as with full-plot monitoring?*

A: GenEst fully compatible with road & pad methods, full-plot methods, or a mixture. Scan-from-pad is designed with eagles in mind which means it calls for a rare event estimator and the generalized estimator is not a rare event estimator. I think if there were a reason to do so we could calculate *g* for the generalized estimator using scan-from-pad data but we have not work out the details of how to do so.

Q: *How do you recommend measuring carcass persistence if raptor carcasses (or any carcasses used for searcher efficiency tests) are attracting scavengers?*

A [Paul]: I do not know how much data there are to support that concern. In most cases you can spread your persistence and efficiency trials out over time so as to avoid that problem.

A [Wally]: Fatality estimation has a lot of field challenges. If we can come up with a consistent approach to fatality estimation, the better – so we can focus on comparing risk rather than comparing estimation methods. Raptor behavior vs. dead game bird – carcass removal is different. We're trying to come up with cost-effective ways to measure things. It might mean that instead of one year of intensive monitoring, you go to longer term monitoring, but with less intensity.

Additional questions not addressed during the session Q&A:

Q: *How do the confidence intervals compare to regular fatality monitoring methods?*

A: I did not show CI in this presentation but for raptors with a 30 day search interval, at the low end of the probability of detection we had 0.5 with 90% CI of (0.3, 0.61) and at the high end we had 0.82 with 90% CI of (0.7, 0.87). I think those compare favorably to regular fatality monitoring methods.

Q: *In my experience, using O&M staff to survey for carcasses has led to incomplete surveying, extensive data gaps and poor quality data. Is the cost savings worth sacrificing the quality of the data you would get using trained biologists?*

A: I'm responding to this question after the conference so first let's highlight some new information: the new eagle rule stipulates 3rd party monitoring for eagles, so the question might be moot. But to answer it anyway, I think that developers have to determine their needs in terms of data quality and cost savings. Good data requires (at a minimum):

- appropriate training with repeated follow-up
- documented procedures and protocol (i.e., drop down categories in data sheets, photographs)
- rigorous QA/QC (data recorder that identifies time and location, data entry inspections, shadowing, blind bias trials, etc.)
- recognition/acknowledgement programs (reinforce and reward good work)
- vocal/visible support from upper-management

I absolutely believe that with adequate training, and if O&M staff have the resources and time they need, they can generate good data, but the monitoring has to be built into O&M work flow; there is no free lunch!

Q: *Do you still anticipate that 3rd-party contractors would do habitat mapping?*

A: I think it likely that contractors could get this done efficiently but there's no special reason it has to be a contractor (except for the new eagle rule stipulations).

Q: *How did you determine that a feathered turkey decoy was a realistic surrogate for an eagle carcass? What tests were conducted? Did you consider that many eagles are reduced to smaller pieces when they collide with a turbine?*

A: We did not have eagle carcasses available to conduct comparative tests between our decoys and eagle carcasses. Our turkey decoys are similar in size, shape and color to eagles. We did not consider that eagles may be reduced to smaller pieces when they collide with turbines, nor that having several bird parts from a single collision may actually increase the probability of detection; this is a seldom-acknowledged weak point in most searcher efficiency trials.

Q: *How do you get reliable fatality estimates when dealing with very low carcass numbers and endangered species? For endangered species, every fatality is significant and discounting carcasses missed on a first search can be problematic. Zero carcasses found cannot necessarily be assumed to mean zero fatalities, in difficult terrain where searcher efficiency is low.*

Wally: You need to use different methods for rare events.

Wildlife Monitoring and Reporting System using Operations Personnel: 5-year Assessment

Presented by Laura Nagy, Avangrid Renewables

Authors: Paul Rabie *(Western EcoSystems Technology, Inc.),* Jerry Roppe *(Avangrid Renewables),* Wallace Erickson *(Western EcoSystems Technology, Inc.),* Amy Parsons *(Avangrid Renewables)*

PROBLEM / RESEARCH NEED

Avangrid Renewables developed a company-specific Avian and Bat Protection Plan (ABPP) in coordination with the U.S. Fish and Wildlife Service (USFWS). The plan was adopted in 2008 and subsequently transitioned into a Corporate Wildlife Plan in 2015. As part of this Wildlife Protection Program, a Wildlife Monitoring and Reporting System (WMRS) is utilized to monitor and internally report wildlife injury and fatalities discovered during operations at its North American wind energy facilities. This is completed through voluntary, long-term operational monitoring conducted by operations and maintenance (O&M) personnel. These O&M personnel monitor and record wildlife injuries and fatalities to assess potential long-term operational impacts (trends) of a Project, or collectively, fleet-wide.

Objectives

The goals of the program are to achieve a level of sensitivity that acts as an early indicator or screening tool on the level of impact, and to assess impacts to wildlife integrated with every-day maintenance activities while encouraging a culture of wildlife awareness. There are four specific objectives:

- Document number bird and bat fatalities and identify large (>5) fatality events
- Document species composition of bird and bat fatalities
- Determine trends or relationships in fatality for bats and birds
- Demonstrate wildlife awareness and ongoing adaptive management

This presentation focuses on the first five-year assessment (2011-2015) of long-term operations monitoring to meet objectives and to identify measures to improve value through adaptive management.

APPROACH

There are three components to operational monitoring:
1. Incidental Observations
   - All personnel
   - Fleet wide (2011- 41 plants, 2015 - 48 plants)

2. Turbine Checks
   - All personnel
   - Pad (gravel) searches during monthly SPCC checks
   - Fleet wide (2011- 41 plants, 2015 - 48 plants)
   - > 170,000 checks

3. Environmental Coordinator (EC) Inspections (with QA/QC)
   - Environmental Coordinator
   - Typically 10 access roads & pads/ plant
   - Seasonal weekly standardized searches (8 weeks in Spring, 10 weeks in Fall)
   - 2011 - 31 plants, 2015 - 48 plants
   - 17,900 inspections

A key factor on validity of the methods is testing the ability of O&M personnel to detect bird or bat carcasses and subsequently assess the application to long-term monitoring. To address this factor, searcher efficiency trials were conducted to evaluate the efficacy of O&M personnel at detecting fatalities during EC inspections at four study sites located across the U.S.

Operational monitoring conducted since 2011 at up to 48 operating projects has generated approximately 18,000 data points (inspections, checks, and observations). This data was evaluated for the following three parameters.

- **Bird/Bat Fatality Detections** – We looked for the occurrence of large events (more than five fatalities) and compared detections by search types and seasonality.

- **Species Composition Fatality Detections** – Species composition data were compared to species composition from over 200 post-construction fatality studies at 139 North American wind farms.

- **Trends and relationships** – We reviewed for evidence of trends in EC Inspection detection rates through time, looked at the relationship between EC Inspection detection rates and published estimated fatality rates at same or adjacent facilities

FINDINGS

The ECs found 105 of 139 carcasses, resulting in a detection level of 76% for all carcasses. This reinforced the use of operations personnel for long-term monitoring of bird and bat fatalities to provide a potential cost-effective approach to monitoring project impacts.
There were no large events, and there were low numbers of detections per search. More bats than birds were found during EC inspection than incidental (Check slide)

Species composition in the monitoring data was broadly similar to species composition from these wind plants, with some difference for horned larks and red-eyed vireos. (Some patterns have to do with where our facilities are located.) Detection rates from operations monitoring were weakly correlated with published fatality rates for bats and large birds, suggesting that detection rates for operations monitoring may be useful as a broad index to overall fatality rates for those groups of taxa or as detecting large anomalous fatality events. There was little evidence for trends in detection rates through time, and no evidence for increasing trends in detection rates (impacts).

The majority of bat fatalities were found in late summer and mid-fall. Seasonality of fatality detection may be slightly skewed by regional concentration of Avangrid plants. But overall the seasonality of discoveries during turbine checks and incidental observation for Overall species composition at Avangrid facilities is broadly similar to national patterns

It was not possible to calculate reliable correlation coefficients between median published fatality estimates and median counts per inspection for large birds or small birds, largely due to the numerous zero median counts per inspection. There was a significant correlation between the median number of bat fatalities found in EC inspections from 2011 to 2015 and published baseline PCM studies at similar or adjacent plants.

CONCLUSIONS / APPLICATIONS

The current assessment demonstrates that operations monitoring using trained on-site O&M personnel provides a general indicator of the level of wildlife impacts, presents a level of sensitivity necessary to trigger responses, and acts as valid approach for understanding impacts levels at operating assets. The Wildlife Monitoring and Reporting System appears to be

responsive to the company's goals, and also creates a culture of wildlife awareness, generating ownership and commitment on the part of operations staff.

Before implementing a similar program, wind companies should consider these factors:
- Purpose/Goals
- Costs/Level of Effort – training and integration of program with company operations/culture is critical
- How the program will aid in ongoing compliance with permits
- Support and recognition for personnel

Questions & Discussion

Q: *Are there measures that can be implemented to ensure that non-independent searchers (i.e., operations staff) diligently and effectively search for carcasses? Cash incentives for finding carcasses, for example?*

A: not in place but we have discussed it. Sometimes have them working in teams, and competition among the teams, that engages operations staff to do the best job they can.

Q: *How are incidental finds by operations staff dealt with alongside a formal monitoring program conducted by those same staff?*

A: incidental finds not included in formal studies. Baseline studies done first.

Q: *What percentage of wind sites are actually doing post-construction studies?*

Laura: We do it at all of our sites. As a consultant, I saw that many companies were doing a lot.

Cris: Difference between how much is being done and how much of what is found is publically available.

Q: *Are there recommendations for met tower surveys? Many met towers have guy wires, leading to significant bird and bat fatalities. Any suggestions for effective deterrents with guyed met towers?*

Wally: Similar survey methods can be used with met towers. A lot of projects now use un-guyed met towers.

Laura: Most permanent met towers are free-standing, not guyed, so have low fatality – we don't search them.

Additional question for Laura:

Q: *Do you still anticipate that third-party contractors would do habitat mapping, training, bias correction, and modeling? What's the approximate cost for this approach?*

A: Yes at some level third-party contractors are necessary to ensure credibility of the data and process. This will vary dependent on the purpose, plant size, location, species of concern, etc. It is a fraction of the baseline fatality monitoring with costs ranging from <$5k to $25k annually.

Operational Mitigation:
Strategies to Minimize Bat Fatalities

Moderator: Ed Arnett, Theodore Roosevelt Conservation Partnership

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Bats in the Rotor Zone...Managing Risk with Acoustics

Presenter: Trevor Peterson, Stantec Consulting Services Inc.; University of Maine

Authors: Trevor Peterson, (Stantec Consulting Services, Inc.)

PROBLEM / RESEARCH NEED

Acoustic bat surveys provide an increasingly reliable and efficient method to monitor bat activity in challenging environments. Acoustic monitoring has been a recommended component of pre-construction surveys at proposed wind projects for a decade or more, with the typical resulting metric being the number of bat passes detected per survey night over an extended survey period. However, this metric has proven to be a poor predictor of bat mortality rates documented through post-construction carcass searches. Carcass searches do not give us a precise time of mortality, so it is difficult to know the precise conditions in which a bat died.

Risk within the rotor-swept zone is highly dynamic, with multiple variables including temperature, humidity, time of night and season as well as wind speed. Instead of being used as a tool to measure overall activity levels, acoustic survey results could be applied far more effectively as a means of actively identifying high risk conditions in the rotor zone.

Objectives

We initiated a long-term study in 2011, using acoustic monitoring at an operating wind project in the northeast to help characterize risk for curtailment decisions. Predicting that the relationship between bat activity and conditions will be consistent, we modeled the relationship between changing conditions in the RSZ and bat activity to help design and optimize wind turbine curtailment program based on multiple parameters.

APPROACH

Our approach treats wind speed and temperature as habitat parameters, the combination of which affects the suitability of the air space for bats. We deployed six to nine Anabat detectors

aimed off the back of turbine nacelles, the direction from which bats tend to approach the risk zone. Acoustic monitoring and concurrent weather condition measurements were conducted over five years (2011-2015) from April to November.

A total of 59,181 bat pass calls were identified visually from the acoustic data. Weather conditions were determined for a total of 635,610 ten-minute periods concurrent with when the acoustic monitoring took place. By mapping the distribution of bat activity according to availability of conditions we were able to characterize conditions where activity was concentrated. We predicted that these would be the conditions with highest risk and designed a curtailment system that fully feathered turbine blades to prevent rotation during these conditions. Additional acoustic surveys and concurrent carcass searches were then conducted to validate the effectiveness of the system at preventing turbine operation during conditions with higher predicted bat risk and reducing bat mortality rates.

FINDINGS

We recorded almost 60,000 bat passes, and the patterns confirmed what we had seen in pre-construction studies. 80% of all activity came from three species, corresponding with bat fatality finds. There were few *Myotis* fatalities, and none under the restrictive curtailment regimes targeting high risk conditions. We were able to correlate the vast majority of bat passes with weather information, primarily focusing on wind speed and temperature.

Comparing bat passes with weather information, we saw that activity is concentrated in the warmest, calmest conditions. 44% of bat activity occurs when wind speeds are below 3.5 m/s. 77% of bat activity occurs when wind speeds are below 5 m/s, 94% below 6.9 m/s. What our analysis allowed us to see is that much of the time that wind speeds are low, temperatures are also below the threshold temperature associated with higher bat activity. When temperatures are lower, simply raising the cut-in speed to 6.9 m/s incurs power loss without avoiding that much bat risk. The relationship between activity and risk is fairly consistent among years, turbines, and sites.

Testing curtailment regimes

In 2013, we designed and tested an initial curtailment regime based on conditions with higher bat activity. Predicted bat activity protected is based on a calculation of the percentage of bat passes (through the previous year) that would be "avoided" through the proposed curtailment plan for each year.

We set a high bar of "protecting" 95% of bat activity from turbine operation, but the percentage could be set at any target level. Night-time cut-in speed was lowest (3.5 m/s) when temperatures were below 7.5 degrees C; cut-in speeds were raised incrementally at higher temperature thresholds – to 5.5 m/s once temperatures reached 10 degrees C, up to 8 m/s when temperatures were at or above 14 degrees C. (We assumed that turbines spinning at under 1 RPM did not pose any risk to bats that might be present.) Standardized searches were performed every 3 days, with mortality calculated using the Shoenfeld estimator.

This curtailment regime resulted in a 24.6% power loss during night-time hours compared with no curtailment under the same wind conditions. Bat mortality was decreased 94% below the level estimated for fully operating turbines in previous years (there were no control turbines for direct comparison).

The plan was modified in 2014 to have a "ceiling" of 6.9 m/s and modified very slightly in 2015 to implement curtailment during a shorter period of the year. All turbines were operated according to the same curtailment strategy in 2013-2015. Mortality reduction represents the comparison of annual (April to November) mortality estimates from study turbines against "control" turbines monitored in 2011-2012. Power Loss was more than halved between 2013 and 2014, with mortality reduction only slightly lower in 2014, indicating that there is substantial room to improve the efficiency of curtailment.

CONCLUSIONS / APPLICATIONS

Air is habitat for bats; acoustics are a useful tool for incorporating other parameters besides wind speed to develop more precise predictors of when bats are likely to be at risk so that curtailment regimes can be more cost-effectively calibrated.

This study represents the first commercial example of a highly effective automated curtailment system designed using site-specific acoustic data and validated with follow-up acoustic monitoring and carcass surveys. Results of this study indicate that analyzing bat activity and weather conditions in the rotor zone can provide a reliable, quantitative method to design data-driven curtailment systems and predict their effectiveness and cost.

This approach can also provide quantitative metrics to help inform adaptive management processes. Acoustic activity as a measure of bats "exposed" to turbine operations during a search interval is a significant predictor of carcass presence. Given a target for reductions, acoustics can be used to refine curtailment so that it is implemented when bats are actually there, as opposed to when they are not.

Questions & Discussion

Q: *Do you think relationships between bat activity, wind speed and temperature that you described would also occur at a "high wind" site where warm, low-wind nights are not typical and bats have to move in windier, colder regimes?*

A: Bats' occurrence during various weather conditions certainly depends on the availability of such conditions, which varies among sites. The relationship between bat activity and temperature and wind speed probably varies among sites, although the same method could be used to identify high risk conditions. I suspect that bats will occur disproportionally during calmer warmer conditions at all sites, although the specific combinations of variables associated with high bat activity will probably differ among sites.

Q: *Did you/could you consider precipitation to refine your model further? Did you look at humidity (dewpoint) and whether it affected bat activity? If so, what did you find?*

A: Yes, there is no specific limit on number of parameters you could include – pressure changes, humidity. However, certain variables (like precipitation) can be more difficult to measure than wind speed and temperature. Also, if you include too many parameters, your predictive ability will likely suffer due to overfitting. We picked the variables we thought were most important, although we recognize that the most important variables might differ among sites.

Q: *One rpm seems conservative as a risk threshold. I've seen 2-3 rpm elsewhere. Can you explain/discuss this choice?*

A: We used 1 RPM as the threshold because we were trying to be as conservative as possible. Once released from curtailment speed, turbines get up to speed fairly quickly. Blade tip speed increases with RPM, although using thresholds of 2 or even 3 RPM would probably have a minimal effect on our results. So far we've also been talking about data in 10-minute data increments; turbines are collecting this info by the second, and the temporal resolution of the analyses could also affect results (as well as the effectiveness of curtailment).

Q: *What has reception been to these "smart curtailment" ideas from agencies?*

A: The response varies among agencies, but in general there is perhaps a bit too much skepticism to considering alternatives to the cookbook strategies. I acknowledge that alternative techniques must be validated, but think that agencies should encourage creative solutions when presented with the opportunity.

Crissy: I would second that. Cost of lost energy productivity are a huge driver for folks not adopting curtailment strategies. If we can reduce that economic barrier to adoption, could improve overall conservation of bats. Agencies really should be open to this.

Additional questions not addressed during Session Q&A

Q: *When you say "when bats are NOT PRESENT" do you mean during the daytime, or during the winter?*

A: No, I am referring to 10-minute intervals at night during which monitoring occurred but bats were not detected.

Q: *Do you think that the power losses associated with this curtailment strategy will be consistent across regions? Power curves in Southern Ontario and Texas, for example, are quite different. Can this be quantified?*

A: All else being equal (threshold wind speeds/temperatures) cost of curtailment will be greater at low wind, warm sites. Given temperature and wind speed data from met towers, you could easily model the cost of curtailment. With the addition of a sufficient amount of passive acoustic data from turbine height, you could also predict the potential effectiveness of curtailment, and our results suggest that these predictions can be highly accurate.

Q: *Were you able to look at conditions specifically related to the few Myotis calls you detected? If so, were conditions consistent with the other species detected?*

A: Yes, this analysis can be conducted on a species-specific basis. In our case, *Myotis* represented less than 0.5 % of bat passes, so sample sizes were small. That said, the small number of *Myotis* passes occurred during calmer, warmer conditions relative to other bat species.

Q: *Do you know what the species composition of the surrounding area was?*

A: Mist-netting conducted on site and in the region can provide some sense of the overall bat species composition in the area, although such data represent the summer maternity roosting period. Most activity (and mortality) occurs during the fall migration period, thus representing regional migratory populations. The resident bat population/species composition often has little relationship to the species composition of bat mortality at a site.

Q: *Can you comment on risk to bats in other sections of the rotor-swept zone – say, away from the nacelle? Do you think your strategy is applicable to bat activity at 30 m above ground level?*

A: Our data are limited to the airspace that was sampled by acoustic detectors (roughly a cone with 60 degree angle extending up to 30 or so meters horizontally pointing away from the back of the nacelle). Although logistically difficult, adding detectors at different heights within the rotor zone could enable a more detailed analysis of the relationship between activity and conditions at different elevations. Presumably, bats are active at higher wind speeds near the ground where trees, etc. provide protection.

Q: *Were you able to correlate bat passes per night or per turbine to a fatality rate? Presumably every bat pass did not result in a fatality.*

A: Nightly analyses are limited by the coarse nature of carcass counts (which have imperfect detection due to searcher efficiency being less than 1, carcass removal by scavengers, and carcasses falling outside of the searchable area). For this reason, and because wind speed in particular is highly dynamic, nightly analyses have a limited ability to characterize the relationship between bat activity, conditions, and mortality risk. Nevertheless, we documented a significant positive relationship between the number of bat passes recorded while turbines were spinning > 1 RPM during intervals between searches and the probability of finding a bat carcasses during the subsequent search. The relationship was much weaker when all bat passes were included (instead of limiting analyses to passes "exposed" to turbine operation).

Q: *How long does wind speed need to be above threshold (i.e., 6.9 m/s) or temperature in order to trigger curtailment?*

A: This varies among curtailment systems. The system we used controlled turbines based on minute-by minute data but included a hysteresis for temperature and wind speed (similar to a thermostat). Few if any studies have conducted detailed comparisons of the effectiveness of

curtailment systems that trigger turbines at different time intervals or differing ranges for hysteresis of controlling variables.

Q: *Does 12% power loss equate to 12% financial loss? If not, what financial impact is associated with 12% power loss? (And why the discrepancy between what Ed Arnett and Michael cited, i.e., power loss of 1% at 6.5 m/s curtailment?)*

A: This varies by project and depends on the power purchase agreements as well as the time period over which analyses are conducted. My summary was based on energy production (probably not equivalent to cost) and limited analyses to night-time conditions during the curtailment period (as opposed to annual production). I do not know whether the numbers other speakers referred to were annual estimates…this would certainly affect the numbers dramatically. Admittedly, use of many different metrics for power loss (time, power production, cost) complicates comparisons among projects, but there's no standardized method of reporting at the moment. To accurately compare metrics, you need to be sure the percentages are calculated over the same duration of period and represent the same metric (proportion of hours, proportion of total power production, proportion of cost, etc.).

Q: *Did you find that the turbine environment produced more noise that you had to account for that would not be present at another location – e.g., a met tower?*

A: Surprisingly, not. We recorded what I consider to be high quality bat passes, often including relatively long passes (many pulses), multiple bats, social calls, and diverse call types (search phase, approach phase, feeding buzzes, etc.)

Q: *Wind speed varies across the rotor – at what height were you taking wind speed and were there corrections being done for a whole rotor look?*

A: Wind speed data came from the nacelle height. Anemometers were about 1 meter above the detectors.

Acoustic Bat Monitoring at a Southern Alberta Wind Farm

Presenter: Katrina Lukianchuk, Tannas Conservation Services Ltd.

PROBLEM / RESEARCH NEED

Over 950 wind turbines (1500 MW capacity total) currently supply 4% of energy demand for the province of Alberta, which still relies heavily on coal. There is a plan to phase out coal by 2030, largely replacing it with renewable energy resources, with wind to play a much larger role. A wind farm in Southern Alberta illustrates the challenge posed by this expansion: located along a major migratory pathway for birds and bats, it poses a high mortality risk to wildlife.

The wind farm has been under post-construction monitoring for two consecutive years, which includes weekly carcass searches and seasonal carcass persistence and searcher efficiency trials to assess mortality rates at each turbine. From this monitoring we know that mainly migratory bat species affected, and mostly during fall migratory period. However, little is known about how the area is utilized by Alberta's bat species in general throughout the year. Carcass searches only provide information about mortality rates, which may not be a good indicator of activity levels of different species. Each species has a unique ecology, which may lead to biases in which species are affected by wind turbines (e.g. forest species vs. open field species, gleaning species vs. species that hunt on the wing, etc.).

Objective

Use passive acoustic monitoring information to help determine when threatened or endangered species are present and at risk in the area of a proposed or operating wind turbine. This includes specific times of the year and hours of the night where they are most active, which could be useful for informing mitigation decisions.

APPROACH

Bats are difficult to track physically, can be hard to find them – but they do vocalize during migration and foraging. Activity is measured in passes, or a series of echolocation calls. Through the use of acoustic monitoring techniques we are able to provide a glimpse of the activity levels of different species of bats throughout the year, including bats that breed in area, as well as bats using the area as a migratory pathway.

Because vocalization structure can reflect a number of characteristics and activities (behaviour, body size, prey size, etc.), we cannot always use it to identify calls to species. Bat echolocation calls may be grouped into high and low frequency bat groups (40K, 30K, 25K, etc.), with *Myotis* species tending to be grouped around the 40 kHz range.

We used Wildlife Acoustic Song Meters to record bats on a nightly basis from sunset to sunrise every night throughout the wind farm (at five locations representative of the project area's different habitat types) to determine general and species-specific bat activity during spring and fall migratory periods, as well as the summer breeding period (March through October). Detectors were positioned at 2 m above-ground level height, with one detector also having an additional microphone placed at 30 m.

We analyzed data with Kaleidoscope Pro (Wildlife Acoustics) and Analook (Titley-Scientific) software packages. Bat calls were identified using both autoID and manual ID techniques.

FINDINGS

Any program that uses auto-identification is not always accurate; we had to group calls into broader categories. Data is presented in passes/detector-night.

Preliminary results show that different species tend to arrive and have peak activity levels at different times of year.

- Silver-haired bats (the most common migratory species in Alberta) and big brown bats tended to arrive first to the area (April) and had peak activity levels in August and September.

- Hoary bats also arrived early (April) and peaked in July.

- *Myotis* spp. bats appeared slightly later (May) and peaked in July.

- In June we saw a lot more little brown and Eastern red bats.

- Long-legged bat and other resident species started to peak in mid-summer (July), when there were fewer silver-haired bats.

- June 1, 2016 saw an anomalous Hoary bat feeding frenzy event on a single day, and we saw more Hoary bats in August in 2016 than we had in August 2015.

Activity dropped steeply in October, with no bats detected past October 17th. Peak hourly activity throughout the night varied depending on the month, but in general was highest from 21:00 to 01:00. Bats were active for a longer portion of the night during the height of the breeding season (22:00 to 04:00 in July) and during the fall migration (21:00 to 05:00 in August and September), with nightly peaks changing a bit over migratory period.

For 2015, silver-haired bats represented a high proportion of fatality numbers throughout. Little brown *myotis* bat fatalities started to appear in May, and disappeared by the end of summer. Hoary bat fatalities peaked in late summer/early fall, and big brown bat fatalities were detected in late summer. For 2016:

- Few little brown bat fatalities were found, disappearing in late summer/early fall.

- Hoary fatalities peaked in summer/early fall.

- Big brown bat fatalities peaked in late summer.

- Silver-haired bats were strongly present among fatalities in April and October.

The fatality searches did not turn up any other species, although sometimes little brown bats are sometimes confused with other *myotis*, and there were some species that could not be identified due to scavenging, decay, damage, etc. We noted that there were fewer little brown and more big brown bats in 2016. It could be that there were fewer little brown bats overall, as this species is now endangered.

CONCLUSIONS / APPLICATIONS

In summary, activity was consistent with what we expected, but with different peaks of activity for different species at different times. Not all species were present in fatalities, but the fatalities we saw did peak consistently with activity peaks. With only two years of data, it is

difficult to explain (or assess the significance of) activity and fatality differences between 2015 and 2016. There is little currently known about species populations, so threshold impact numbers are somewhat arbitrary.

These data are useful for determining baseline activity levels of different species of bats in southern Alberta, an area where wind farm development is growing quickly. Mortality data from carcass searches alone may not be enough to make informed decisions about future wind farm developments and mitigation techniques. Acoustic monitoring could be a useful passive technique to help us understand how to micro-site, and also to help inform post-construction mitigation in a way that carcass searches alone cannot.

Going forward, we need to determine how to collect data that best represents activity across entire site, perhaps with microphones at different heights for different species. Comparing acoustic and mortality data can help us understand which species are being affected the most, and which may be avoiding effects of wind farms. It can improve local bat ecology knowledge for an area, which can eventually inform policy to protect Alberta's bats.

Questions & Discussion

Q: *Any thoughts on the difference in species composition that was observed through the acoustic monitoring vs. the fatality searches? Is it easier for some species (e.g., Myotis) to detect activity using acoustic monitoring than it is to detect fatalities?*

A: Some species fly at different heights, so important to get microphones at different levels. Could have to do with species-specific behavior, whether they are attracted to turbines. Can be challenging to tell them apart. In terms of difficulty detecting different species during fatality searches, not a huge difference between species (except for maybe hoary bats which are larger than *Myotis* species, and therefore easier to see). It's likely that the difference seen in species composition between acoustic monitoring and fatality searches is simply that some species that pass through the area are less likely to be affected (i.e. not attracted to turbines, or not flying at an appropriate height to be killed, etc.).

Q: *Did you see a difference between 2015 and 2016 fatalities, as you saw differences between the acoustic data for those years?*

A: The slides showed a slight differences in species composition (e.g. more hoary bats and fewer *myotis* species seen in 2016). Since I was working with proportional data, I can't comment on differences in quantity.

Additional questions not addressed during Session Q&A

Q: *Any myotis fatalities besides little brown bats? Can you speculate why myotis fatalities are low?*

A: We didn't document any other *myotis* species fatalities, though often some species can be difficult to tell apart by non-experts. *Myotis* species in general were less abundant than hoary

bats and silver-haired bats (according to the acoustic data), but they are also non-migratory species, so they tend to be less affected than migratory species are. There may also not be any roosts located nearby to this wind farm, which would reduce the level of activity and quantity of individuals using the area.

Q: *Was there a difference between the acoustic data gathered at the ground level vs. at elevated stations? Which had greater activity?*

A: We haven't looked at this comparison yet.

Q: *How close was your project to the Rocky Mountain Front (foothills)?*

A: Very close.

Q: *Why did you decide to survey from April to November?*

A: Yes, this was part of the post-construction monitoring plan, and coincides with fatality searches. We wanted to see when bat activity begins in the spring as well as the fall, as we do begin to see carcasses as early as April.

Q: *How do you retrieve data from the acoustic monitors?*

A: Data are stored on SD cards within the monitors and need to be manually collected on a regular basis. Song meters from Wildlife Acoustics can hold several SD cards at a time, and therefore can record data for long periods of time, battery life permitting.

Turbine Integrated Mortality Reduction for Bats

Presenter: Christine Sutter, *Normandeau Associates*

Authors: Christine Sutter (*Normandeau Associates*), John Goodrich-Mahoney (*EPRI*), Sue Schumacher (*We Energies*)

PROBLEM / RESEARCH NEED

We know that bat fatalities are non-random. We do see higher bat activity at lower wind speeds, but there is some activity at higher wind speeds, and more importantly, low wind speed not a good predictor of bat activity. In our study curtailment based on wind speed alone would have wasted 75% of the curtailment hours because no bats were present during 75% of the low wind speed hours (≤6.9m/s). This is similar to what other researchers have found (25-42% of curtailment hours wasted when wind speed is the only variable considered).

Curtailment regimes based on wind speed only therefore result in wasted curtailment hours, thus raising the cost of curtailment without reducing mortality, which presents a barrier to adoption of curtailment by wind facilities. Instead of trying to predict when bats are exposed to the turbine rotor swept area, why not measure actual exposure and trigger curtailment in real time?

Objective

We developed and tested a system that uses real-time acoustic data to trigger real time curtailment while staying "outside" of the supervisory control and data acquisition (SCADA) system. Our goal was to generate a high conservation benefit (fewer fatalities) at a lower economic cost (fewer curtailed hours) and develop the supporting portable infrastructure.

APPROACH

The Turbine-Integrated Mortality Reduction (TIMR) system receives and processes acoustic data continuously from nacelle-mounted acoustic monitoring systems. Weather data values are available every ten minutes from a single nacelle-mounted weather station. Data is streamed to the TIMR server, which automatically calculates a real-time risk value that determines the relative risk of bat fatality and thus whether the turbines at the wind energy facility should continue to operate or curtail (curtail = blade rotation of 2 RPM or less). The risk value and corresponding operation decision is communicated every ten minutes to the SCADA.

The minimum curtailment period is 30 minutes, with extensions in 10 minute increments after that as needed. Curtailment rules were as follows:

When wind speed is…	Then…
<3.5 m/s	curtail (RPM<2)
3.5 to <8.0 m/s AND	
- *Bat activity at/above threshold*	*curtail (RPM<2)*
- *Bat activity level below threshold*	*continue to operate normally*
≥8.0 m/s	continue to operate normally

We conducted an EPRI-funded study of the TIMR system at the We Energies' Blue Sky Green Field 88-turbine wind facility near Fond du Lac, Wisconsin. During the 2015 fall migratory season (July 15 to September 30), ten turbines operated normally and ten turbines operated under the TIMR rules. The treatment was implemented from 6:00 pm to 6:00 am, and the 20 turbines were searched daily for bat carcasses.

FINDINGS

The model was good at curtailing the turbines during the right times when exposure (risk) was high. It curtailed only 25% of low-wind speed hours, but reduced overall bat fatalities 83% – with a 90% reduction in *myotis* fatalities– as compared to the normally operating turbines. This is the first demonstrated reduction in *myotis* fatalities. Results were consistent at 10 control and 10 treatment turbines. Results were consistent across species.

The lost power generation under TIMR was 90 MWh/turbine/season. This is substantially less than under a 5.5 m/s cut-in speed scenario (150MWh/turbine/season) or a 6.9 m/s cut-in speed scenario (225 MWh/turbine/season)

The study also showed a strong correlation between bat activity and mortality, validating the use of activity data to inform real time curtailment.

At this low wind speed, low capacity factor site (27% capacity vs. median capacity of 38%) the revenue loss was $3,520 per turbine per year (90 MWh/turbine x $40/MWh). If all 88 turbines had been operating under the TIMR system, the loss would have been approximately $316,000 per year. This is less than half of what the wind energy facility would have lost if curtailing all turbines under a 6.9 m/s cut-in speed regime.

CONCLUSIONS / APPLICATIONS
The successful implementation of TIMR allows wind energy facilities to maximize bat conservation while minimizing loss of energy and revenue. It has the potential to increase operational time 50%. That it is able to communicate with SCADA without actually physically integrating with it, makes this a very portable application.

Questions & Discussion

Comment: *There is some criticism of acoustic detection methods, as to whether bat pass calls equate to multiple individuals or a single individual passing multiple times.*

Responses:

Crissy: Acoustic monitoring provides an index of activity; it does not provide a count of bats. However, if the index is a useful indictor of relative risk (not absolute risk), then this index can be useful in managing fatalities.

Trevor: Acoustic detectors are unable to differentiate individual bats (unless they are of different species). However, this does not affect the ability to determine when bats are active within range of a detector, allowing us to determine the conditions under which bats are active. The question for us is not how many passes we record, but the conditions during which bat activity occurs.

Questions specifically addressed to Christine Sutter:

Q: *How many TIMR units are needed – one per turbine? Some percentage of turbines? What would be the approximate cost to implement this system?*

A: Only one TIMR unit is required per site. How many acoustic monitors you need is another question and depends on the site. At the study site, we acoustically monitored about 5% of the turbines (4 of 88) so we suggest that 5%–10% of the turbines should have acoustic monitors on the nacelle. Assuming five acoustic monitors, then a TIMR system will cost about $250,000 in Year 1 and about $30–40,000 per year starting in Year 2.

Q: *Did you explore how to feed the curtailment information to a real-time forecast submitted to the energy market?*

A: We did not explore this option. It would seem to be an easy task since the data flow is automated and we can program the data to flow to the destination(s) of your choice. So if it would be beneficial to have that data flow to another computer or person that is calculating economic costs that can be easily accomplished.

Q: *Have you considered how feathering below 3.5 m/s at TIMR turbines contributed to the results? What was "standard" curtailment as compared to "model" curtailment?*

A: Yes, there would have been a 50% reduction in fatalities by just curtailing below 3.5 m/s.

Q: *Is there an alert to a failure in acoustic detector function? What is the lag time for detection of device failure?*

A: "Failure" of the system could be for a few reasons: if the acoustic monitors were not operational and thus did not detect bat calls or if the TIMR server was not operational. However, we have built-in system health monitoring for each of these subcomponents for the TIMR system. The acoustic monitors undergo a health check every 20 minutes. The health of the TIMR server is monitored continuously. In either case, the alerts are sent immediately and

allow rapid response and repair if needed. Note that during the 2015 study the operational time was >99% and the non-operational time was due to turbine shut downs to facilitate turbine maintenance/repairs. Also the ReBAT® acoustic monitoring systems have been in use since 2008 and we have collected over 60,000 hours of acoustic data using these remotely managed systems, and in the last few years they have had an average uptime >98%.

Additional questions not addressed during session Q&A

Q: If you had more detectors, would you be able to drop mortality further?

A: The reduction in mortality is not directly tied to the number of detectors. It is related to synchronizing the curtailment with the activity so that when there is relatively high activity the turbines are curtailed, and when there is no or relatively low activity there is no curtailment. Adding detectors may or may not improve this synchrony.

Q: How do you define and measure risk? Specifically, how did you determine what activity level (e.g., bat passes per time interval) would trigger curtailment? Were different activity thresholds used for different wind speeds between 3.5 and 8 m/s?

A: Since we were monitoring activity at so few turbines (<5%) the activity threshold to trigger curtailment was one bat pass. We used this threshold for all wind speeds (3.5 to 8). However, at a higher activity site or if more turbines were instrumented with acoustic detectors, then a higher threshold may be applicable.

Q: What is the reaction time to slow turbine rpms to a level that would protect any bats present?

A: It took between 1 and 2 minutes.

Q: What is the range for acoustic monitoring? Do monitors at the nacelle detect bat activity out along the blades? How are the acoustic monitors attached to the turbines?

A: The range of the AR125 mics is up to 75 m but more typically around 65 m. The exact detection distance varies with the atmospheric conditions (e.g., relative humidity) and with the echolocation call characteristic of each species (e.g., some species' calls can be detected at longer distances than others).

One ReBAT unit is attached to the nacelle, not the blades. It has two mics, one with a reflector plate that looks up and one without a reflector plate that looks down. Together they roughly cover the rotor swept zone.

Q: Are acoustic detectors as effective at detecting bat calls under higher wind conditions as under low-wind conditions? Any indications that bats vocalize more or less during high vs. low wind speeds? WS?

A: There is no evidence that bats do not echolocate when aloft. Some researchers (Van Gelder 1956; Crawford and Baker 1981; Timm 1989) have suggested that bats might not echolocate

during migration but no evidence has been presented to support this statement. Also Speakman and Racey (1991) demonstrated that echolocation is a zero-cost activity for bats in flight and since collision with objects (fence, cactus, other bats) incurs a high cost (injury or death) there should be little incentive for bats to remain silent.

Q: Is the cost of curtailment ($316,000 for 88 turbines) considered a lot or not so much revenue lost?

A: That is a difficult question to answer because whether it is "a lot" depends on how much total revenue the site is generating. In the case of Blue Sky Green Field the lost energy production was 90 MWh/turbine, which has a $40/MWH market revenue value so the lost revenue was $316,000. This is about 2% of the total annual revenue. This is on the low end of the economic impacts reported by others. Studies by Baerwald et al. (2009), Arnett et al. (2011), and Martin (2015) reported a loss of 1%–5.3% of annual revenue at a given wind farm.

Q: Do you expect any differences in effectiveness of TIMR system across sites?

A: I expect that the reduction in mortality and the total amount of curtailment will vary by site because of the inherent difference in the bat activity patterns and the wind speed regime at each site. That said, I think the premise of curtailing when bats are present is sound and should be broadly applicable across a wide range of sites and species.

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Smart Curtailment: Improving Efficiency by Using More Than Wind Speed

Presenter: Manuela Huso, U.S. Geological Survey,
Forest and Rangeland Ecosystem Science Center

Author: Manuela Huso (*U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center*), Joseph Maurer (*Oregon State University*)

PROBLEM / RESEARCH NEED

Members of the American Wind Energy Association have voluntarily agreed to curtail rotation of turbine blades below manufacturer cut-in speed (MCI: the wind speed at which turbines operating normally are able to send power into the grid) to reduce bat mortality. In some areas, regulators require additional curtailment at wind speeds higher than MCI during the peak period of bat migration. The Multispecies Regional Habitat Conservation Plan (HCP) currently in review after open public comment suggests a fixed time period for curtailment: August 1 – Oct 31. Raising the cut-in speed appears to be effective in reducing bat mortality, but incurs unanticipated losses in revenue.

One of the most frustrating parts of the puzzle of understanding the impacts of wind development on bats and what to do about it is that we don't know when the bats are killed. We only know that we find dead ones the next morning – sometimes more, sometimes fewer – but so far, we have no reliable commercial method for determining exactly when the bats collided with the blade that would allow us to correlate weather and other factors to the fatality. We are left with fairly coarse relationships that relate mortality (the number of bats per turbine per night) only to summary statistics of the fateful night, e.g., average wind speed. These summary statistics may not reflect the period when fatality occurred, which is unsatisfactory on two counts.

1. Just because the average wind speed was fairly high, it is possible that the fatality actually occurred during the part of the night when winds were relatively low or vice versa, just because the average wind speed was fairly low, it is possible that the fatality actually occurred during the part of the night when winds were relatively high.

2. Most of the summary statistics we have used so far can only be calculated after the night is over, making it difficult very difficult to act on them without assuming that a relationship observed on a nightly basis with a nightly average will translate to a relationship in a real-time basis.

- Are there measurements we can make and respond to BEFORE the night begins that are related to mortality

- Can we develop a simple algorithm that will result in fewer bats or lower cost (or both) than current proposal for a particular period?

NOTE

A detailed summary of Dr. Huso's approach, findings and conclusions are not available for publication with these Proceedings, pending peer review.

Multi-year Operational Minimization Study in West Virginia: Potential Novel Strategy to Reducing Bat Fatalities at Wind Turbines

Presenter: Michael Schirmacher, Bat Conservation International

[presentation]

Authors: Michael Schirmacher (*Bat Conservation International*), Alex Prichard, Todd Mabee (*ABR, Inc.*), Cris Hein (*Bat Conservation International*)

PROBLEM / RESEARCH NEED

Post-construction fatality surveys suggest that bat fatalities are highest when turbines are operating during low wind speed conditions. In general turbine operations terminology, the start-up speed is the wind speed at which blades begin to turn, whereas the cut-in speed is the speed at which the turbine begins to generate useable energy. Slide #3 shows cut-in speed graphed against wind speed and tip speed for three different turbine types. Note the relatively high tip speed even before the turbine generates usable electricity.

Limiting blade rotation or "feathering" at relatively low wind speeds (e.g. <5.0 m/s or <6.5 m/s) has proven to be successful in reducing bat fatalities at wind turbines. Yet, this relatively cost effective strategy can likely be improved. Strategies that reduce power loss while maintaining the conservation value are needed to maximize adoption.

Objectives

In 2012, we initiated a 3-year study at a wind energy facility in West Virginia to test the effectiveness of different operational minimization strategies to reduce bat fatalities. The first

objective was to test different curtailment wind-speeds threshold (i.e. traditional operational minimization), and the second was to try to improve the cost-effectiveness of "traditional" operational minimization strategies by adjusting the time period to initiate turbine start-up time, and also whether that measurement was taken at the turbine anemometer or at a met tower.

APPROACH

In 2012, we tested normal turbine operation (3.0 m/s cut-in) versus turbines that were feathered below 5.0 m/s for the first four hours of the night and for the entire night. All operational changes are based on 3-minute wind speed averages measured at the meteorological (met) tower.

In 2013, we tested normal turbine operation versus increased cut-in speeds of 5.0 m/s all night and 6.5 m/s all night, with operational changes based on 10-minute wind speed averages measured at the met tower.

In 2015, we used the 5.0 m/s cut-in all night based on 10-minute wind speed averages at the met tower as the control group, since turbines were operating under that regime as a minimization strategy at the site during the autumn migration period. We compared this control group to two treatments using 20-minute wind speed average measured at the met tower vs. with the turbine anemometer.

Fatality estimates were based on daily searches at 15 of 23 turbines, using a randomized block design, with treatments rotated nightly. We used the Huso estimator to estimate mortality, and a Bayesian Poisson regression to model observed fatality by treatment. A secondary analysis used a Logistic Regression Mixed Model to look at factors that influenced bat fatality when turbines were spinning.

FINDINGS

Results in West Virginia for 2012 and 2013 were similar to what has been found in other studies [Slide #4]. Estimated fatalities were similar at the 5.0 cut-in speed for both years.

- In 2012, we found a significant difference between 5 m/s-all night and the control group, but no difference between the control and the 5 m/s-half night treatment. The 5 m/s-all night treatment showed an average reduction of 47%.

- In 2013, we found a significant difference for both the 5m/s and 6.5 m/s all-night treatments (based on 10 minute average wind speed) versus the control, but no significant difference between the two treatment groups. The 5 m/s treatment showed an average reduction of 58%, and the 6.5 m/s treatment showed an average reduction of 75%.

In 2015, all treatments involved feathering up to 5 m/s cut-in speed. Using a randomized block design, we looked at fatality by treatment two different ways: 1) whether a 10-minute or 20-

minute rolling average was used to determine the threshold wind speed; and 2) whether the wind speed was measured at the turbine nacelle or at a met tower.

Many turbines use a rolling average of wind speeds over a 10-minute period to initiate turbine start-up, although measuring wind speed over such a short period of time might be inflated by wind gusts – causing turbines to operate prematurely and thereby increase risk to bats. Moreover, air is less turbulent at the met tower than at the turbine nacelle which could affect the effectiveness of this minimization strategy. We hypothesized that longer measurement of wind speed before initiating start-up (i.e. 20-min vs. 10-min average) would result in fewer fatalities, and that "free-flowing" wind speed measurement (that is, at the met tower rather than at the turbine anonometer) would be more accurate and result in lower fatalities. [See slide #8.]

Our 2015 results indicated significantly fewer bat fatalities occurred when turbine operations were based on the wind speed data from the met tower rather than individual turbines. Wind speed measured at the turbine nacelle was greater than wind speed measured at the met tower 97% of the time, with the difference averaging 1.03 m/s higher. Extending the decision time from a 10-minute to a 20-minute wind-speed average to initiate start-up may also have contributed to lower fatalities by reducing the number of transitions (i.e., turbine start-ups and shut-downs) or by reducing the operating time during low wind periods. Slide #15 illustrates the high correlation between stops/starts per night and the probability of finding fatalities the following day. Minimizing the number of start-ups/shut-downs also may assist in reducing wear-and-tear on turbines and, at least in this study, may reduce the power loss related to this minimization strategy.

CONCLUSIONS / APPLICATIONS

In summary, for this study the treatment using a 5 m/s cut-in speed based on a 20-minute rolling average measurement of wind speed at the met tower was the most cost-effective.

- Significantly fewer fatalities than Turbine 20-min
- Fewer fatalities than Met 10-min
- Less power loss and turbine on/off than Met 10-min
- More energy production even though less operational time (perhaps because of fewer stops and starts)
- Less turbine "wear and tear"

In comparing study results over three years [slide #18], using the longer rolling average at 5 m/s resulted in similar estimated fatalities to raising the cut-in speed to 6.5 m/s, although this might be related to annual variation in fatality and needs to be verified. To better determine the cost-effectiveness of this novel strategy, future research should investigate the potential of modifying "traditional" operational minimization strategies by increasing the decision time to initiate turbine operation in other regions and test as an alternative to raising the cut-in speed greater than 5.0 m/s.

Next steps include:

- Replicating these results at other wind energy facilities, possibly increasing the time difference between the treatments

- Testing the trade-off between longer decision framework vs. higher cut-in speed

- Using thermal videography to address potential risk to bats at start-up and to determine lethal tip-speed

Questions & Discussion

Q: *Can you do "ON" using 20 minutes of data and "OFF" using 10 minutes of data? How do you think that would change fatality, power loss, and wear-and-tear?*

A: All treatments had a ten-minute off.

Q: *If yes, please hypothesize how that would change fatality, power loss, and wear and tear on turbines.*

A: Our top model included only stops but starts and start/stop were within 1 AIC unit. Our data showed that stops and starts were highly correlated, making it difficult to determine the period of highest fatality risk. Thermal videography might be a better tool to assess risk to bats as turbines operations transition (i.e. start-up or shut-down). Moreover, in our study we could not separate stops and starts from risk to bats when wind speeds were around the operational threshold (i.e. 5 m/s), so risk during stops could be an artifact of higher risk to bats at relatively low wind speeds (i.e. when turbines are more likely to stop and start).

Additional question not addressed during session Q&A:

Q: *Any comments on real-time curtailment impact on grid operations?*

A: Knowledge of grid operations and stability are outside of my expertise. Assuming risk to bats is highest in the late summer-fall, which is reasonable for areas like West Virginia, we showed that this time period has, on average, the lowest wind speed and data suggests this is the period with the lowest energy demand across the U.S., likely even less demand at night. These factors plus the relatively low power loss of feathering turbines at low wind speeds, may reduce the influence of this strategy on grid operations and stability.

Examining Species' Responses and Vulnerability to Wind Energy

Moderator: Ryan Zimmerling, Canadian Wildlife Service, Environment and Climate Change Canada

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An Evaluation of Potential Pronghorn Responses to Wind Energy Development in North-Central Arizona

Presenter: Martin Piorkowski, Arizona Game and Fish Department

[presentation]

Authors: Martin Piorkowski, Daniel Sturla, Joel Diamond (*Arizona Game and Fish Department*)

PROBLEM / RESEARCH NEED

As a state wildlife agency, much of the Arizona Game and Fish Department's work is funded by hunting license tags, so there is a lot of interest in game species. Pronghorn (*Antilocapra americana*) are one of the most susceptible ungulate species to anthropogenic disturbances, including various forms of energy extraction. Today pronghorn face a new, ever increasing presence on the landscape – wind energy facilities. Approximately 36% of all U.S. wind energy production occurs within the core distribution of pronghorn yet there is little published or unpublished research as to how wind turbines may impact pronghorn.

The impetus for this study was concern for a pronghorn herd in North-Central Arizona, an area comprised primarily of grassland plains used as rangeland, with some interspersed juniper woodlands. There are three subspecies of pronghorn in Arizona, but we were focused specifically on how the most common American pronghorn (*Antilocapra americana americana*) interact with the Dry Lake Wind Facility, and whether the animals would display any avoidance to the facility or its turbines.

Objectives
The three primary objectives were to:

1. Identify movement patterns within and near an operational wind facility in north-central Arizona.

2. Evaluate any measurable impacts the wind facility may have on pronghorn movement patterns, including distribution of crossing locations, and annual and daily variations in frequency and as a function of the facility's operational status.

3. Collect pre-construction movement data for future planned wind energy development in the area.

APPROACH

We designed a study that measured pronghorn movement patterns using Browning Bridge Movement Models to calculate utilization distributions of free-ranging pronghorn in and around a wind facility. In 2010-2011, we captured 17 female and 7 male pronghorn and fitted them with satellite telemetry collars. These collars collected location data eight times ("fixes") per day from the 24 individuals for 24 months (2010 to 2013), giving us a total data set of nearly 56,000 location fixes.

Using raw collar data at 4-hour increments, we connected consecutive points to form a single movement event for each animal. We selected those movements that intersected a turbine segment, distinguishing between interior and exterior (spans at the end of turbine strings) turbine crossings. Each crossing was associated with parameters (date, time, sex of the animal, wind speed, segment length, and distance to the nearest turbine) that corresponded with that movement segment. (We are still collecting additional data on potential covariates for future analyses.)

We used the location data to calculate core (50%) and primary (95%) utilization distributions and travel distances for each pronghorn.

FINDINGS

Twenty-one of the 24 pronghorn utilized the wind facility; the other three had been collared south of the study area and did not interact with the facility. Five percent (5%) of all movements involved crossings between two turbines, with 14.5 crossings per segment between exterior (end-of-string) turbines, and 23.5 crossings per segment between interior turbines. This did not constitute a statistically significant difference (p = 0.275).

Overall distribution focused on north-central and southeastern portions of the study area. High crossing rates were associated with open grassland, especially in the winter, whereas in the summer, pronghorn were more likely to utilize the pinyon and juniper wooded areas. Intermediate crossing rates were associated with minimum pinyon/juniper and elevated areas. Low crossing rates were associated with the heavily pinyon/juniper-encroached areas, with slash piles of wood/debris sitting on the landscape. Pronghorn tend to avoid such areas.

Male pronghorn crossed further and more towards the center of the span between turbines compared to females, and crossed less frequently (23.8 vs. 64.6 crossings/individual, respectively) between turbines than did females. This was true both for operating turbines and for those with non-moving turbine blades. Finally, pronghorn tended to utilize the areas within

the wind facility more often in the winter months (November through February) than the summer months (April through October). There was no diurnal pattern (552 crossings took place during daylight hours vs. 520 at night.

CONCLUSIONS / APPLICATIONS

Overall, we did not find any evidence that suggested pronghorn were avoiding the wind facility. However, we did identify that male pronghorn tended to cross more towards the center between turbines, maximizing distance from the turbines. Additionally males crossed between turbines less frequently than did females although they both utilized habitat immediately adjacent to the turbines.

These results suggest that pronghorn populations may not avoid otherwise suitable habitat in the presence of an operational wind facility. However, there may be management practices available that could improve connectivity and permeability for males with specific attention to turbine micro-siting, such as small increases in inter-turbine distances. By retaining or improving connectivity through contiguous habitat via fence modifications, removing slash piles and other vertical structures, minimizing physical disturbance, and restoring or improving those areas quickly during and post-construction, pronghorn should continue to utilize the landscape without experiencing negative impacts with the operation of the turbines.

Questions & Discussion

Q: *Four hours between location point fixes introduces high uncertainty about exact crossing location of a meandering species. Did you look at more frequent data collection to evaluate effort of points relative to lateral movement?*

Martin: We wanted to be consistent with other Arizona Game & Fish studies of pronghorn herds in other areas outside this project. Could have tried some shorter durations in the mornings and evenings, longer durations at night. But we wanted to stick with consistent protocols so we could compare with other pronghorn populations in Arizona.

Q: *Was there any baseline data collected prior to the creation of the wind farm? If so, was there any change in pronghorn use from pre- to post-construction? If not, will this be looked at in the future?*

Martin: There was no baseline data collected pre-construction – observational data only. In the future, some there is some interest in continuing to monitor that population in 3-5 years. As of now, information collected for this project will be baseline for future projects if they are developed in this area.

Q: *Did you look at pronghorn use as a function of habitat, without considering turbine presence? For example, overlaying habitat types with use density location data?*

A: Resource selection function analysis – in short, we did not include that. It's a very small area, and movement is constrained to level topography, with all of that being used at least at some

time of year. The facility sits on top of a rise with a cliff on one side, and density of use is most frequent in level areas within the site.

Additional questions not addressed during Session Q&A

Q: *What fence modifications have you found to be effective in minimizing collision risk/impacts to pronghorn?*

A: This was not the focus of our study, however, there is existing work being done with fence modifications and pronghorn. Currently there is strong evidence that modifying the bottom wire to be 18 inches from the ground which allows pronghorn to move more freely under fences. Arizona Game and Fish is currently practicing and encouraging landowners to adopt "pronghorn friendly" fences.

Q: *Did you notice increased use around turbines that could be associated with forage from project reseeding/restoration or use of turbines for shade?*

A: This is a two-part question. First, this project has been in operation since 2008. It is difficult without turbine-specific vegetative analysis what potential food source may have been reseeded forage and what may be new native forage. Second, the use of shade has only been noted incidentally. Although it appears that pronghorn may seek the shade from a turbine, there has been no quantitative data collection on sun exposure vs. shade.

Q: *Did you find that any pronghorn avoided the wind farm completely? (Does facility disrupt migration routes?)*

A: The three individuals that did not utilize the farm we collared south of the facility (beyond 3 km). They never came within 3 km of the facility, and it is difficult to explain that behavior. They may have been constrained by other factors (such as fences) from the facility. Additionally, this is a non-migratory population of pronghorn so it would be difficult to speculate how migratory populations may perceive these structures during migration.

Q: *Did or will your study influence AZ Dept of Game and Fish management or permitting for wind?*

A: I cannot speak for the regulatory personnel at Arizona Game and Fish Department, but those folks can use any and all data available to them for permit evaluation.

Q: *Do you expect to see habituation of pronghorn as we have seen for wildlife crossings for other large mammal species (e.g., caribou and pipelines)? Anything supported by the literature?*

A: I think that our study indicates minimal disturbance to pronghorn after the turbines have been constructed and are in operation. As with other studies concerning other species (elk, caribou, etc.) there is an expected avoidance during construction, and I would expect no difference in pronghorn. However, the question remains as to how long it will take for the pronghorn to re-establish "normal" behavior.

Q: *Any change to pronghorn reproduction around the wind farm?*

A: This was not within the scope of our work and would likely take many years to assess this focused level of productivity measurements with statistical precision.

Modeling the Impact of Wind Energy on Hoary Bat Populations

Presenter: Erin Baerwald, University of Calgary and American Wind Wildlife Institute

PROBLEM / RESEARCH NEED

Wind energy is an increasingly popular alternative to natural gas and other fossil fuels for producing electricity. As wind energy capacity has increased, bat collision fatalities have also increased.

One study estimated that 0.84 to 1.7 million bats – representing 22 of 47 possible species – were killed in the U.S. and Canada from 2000-2011, with the number of fatalities increasing each year. The majority of the fatalities (78%) are migratory tree-roosting bats, including silver-haired bats (19%), Eastern red bats (21%), and hoary bats (38%). To date, none of these are listed bats, but fatalities at a given facility could have implications for populations across the continent. Bats have a slow life history and low reproductive rates, so we assume that fatalities have a larger impact than for shorter-lived faster-reproducing animals. The three species most affected by White Nose Syndrome, cave-hibernating bats, (tri-colored bats, little brown Myotis, and Northern long-eared Myotis) represent over 12% of fatalities.

One challenge in evaluating potential impacts is that we do not know much about bat populations, especially tree-roosting migrants like the hoary bat. It is very challenging to count or catch and mark and track them. What to do?

Objectives

Our objective was to determine whether current estimates of collision fatalities threaten the North American population of hoary bats. We chose hoary bats because they are the bat species most frequently reported as collision fatalities.

APPROACH

The U.S. Fish & Wildlife Service asked nine bat experts to estimate four demographic parameters for hoary bats: adult annual survival, first-year annual survival, adult fecundity, and first-year fecundity. This was a four-step elicitation; experts were asked to provide a lower bound, an upper bound, a most likely estimate, and a confidence level. This exercise continued

until all experts were over 80% confident in their estimates, which occurred after the fourth round of elicitation.

Experts used these parameters to support population modeling for hoary bat as follows:

- Calculated population growth rate (λ) as the dominant eigenvalue from a 2-stage Lefkovitch matrix using the 'most likely' vital rate estimates

- Estimated hoary bat fatality rate as 38% of the 2014 estimated cumulative bat collision fatalities or **128,469** bats/year. This number was divided by N_i, the initial population size, to calculate the proportion of the population killed by wind turbines (F_{wind}/N_i). This proportion defined as the per capita fatality rate, which was held constant for a given N_i throughout the simulations.

- Projected 10,000 simulations of stochastic population growth over 50 years with and without collision fatalities at wind turbines, using nine scenarios:
    - Three initial population sizes (the lowest (N_{lo}), median (N_{med}), and highest (N_{hi}) of the 'most likely' expert elicitation estimates).
    - Three values of λ (calculated from expert elicitation vital rates) applied to each initial population size.

FINDINGS

We used repeated measures analyses to examine how fatality rates change through time at 53 North American wind facilities with two-years of post-construction monitoring. Fatality rates declined in the second year of monitoring at 63.5% of wind energy sites examined, and the mean fatality rate was significantly lower overall in the second year of studies. This decline may indicate that bat populations are declining, but further studies are needed to test this hypothesis.

Simulation results using the expert-informed population model suggests that current collision fatality levels could cause a 91% decrease in the continental population of hoary bats within 50 years. Collision fatalities had no observable impact on hoary bat populations when the initial population was greater than 4 million and baseline growth was at least 3% per year ($\lambda = 1.03$).

CONCLUSIONS / APPLICATIONS

The modeling did not evaluate the effects of current mitigation efforts (curtailment at low wind speeds) on the models' predictions; neither did it alter fatality rates with increasing capacity. The analyses highlight the need for effective mitigation strategies that embrace adaptive management and address cumulative impacts as more turbines are built; reports [at this research meeting] about curtailment strategies are very promising.

Q: Thinking 10-15 years ahead and there are 3 times the number of wind turbines on the landscape, and no additional mitigation than what we know about today – what's impact on animals?

A: It depends what the starting population is and the estimate of population growth. If they are what the experts estimated, we would expect the hoary bat population to decline at least 50%. However, we don't know how per capita fatality rate changes if the hoary bat population declines over time.

Q: *How did the methods behind hoary bat population estimation compare to those in USFWS' 4(d) rule – biological opinion for Northern long-eared bat, which estimated a population of 6.5 million adults?*
A: The species are quite different and may have different starting population sizes; density of hoary bats may be much lower. It's easier to count long-eared bats because of hibernacula counts being done well. Decline of northern long-eared bats has been severe because of white-nose syndrome.

Q: *Could the variability in hoary bat mortality rates observed between years be an example of annual variability in migratory patterns rather than evidence of a decline in population? Or if there are in fact fewer bats available to be killed in the second year, couldn't that be due to factors other than wind affecting populations and migration patterns?*

A: We see a decline in fatalities across the board at a wide variety of sites and across a range of years, which does suggest a broader basis for the decline, rather than a shift in migratory patterns. However, the cause of the decline remains uncertain.

Q: *Did your conclusions about wind energy impacts take into account that there are many wind projects currently curtailing to decrease bat fatalities? Can you factor in a population model where mitigation is applied, to show the effect of that at the population level?*

A: We did not consider that for the population modeling portion, but that could be a further elaboration of the modeling effort.

Additional questions not addressed during Session Q&A

Q: *Has any population genetics work been done in addition to this effort?*

A: Yes, there have been a few population genetics studies conducted on hoary bats. Most studies suggest a single panmictic population, with smaller effective population sizes than other comparable bat species.

Q: *Was there evidence from population surveys that λ was greater than 1.0, or just from estimates of survival and fecundity?*

A: The λ values we used came from the life-history variables estimated by the experts. There have been no population surveys.

Q: *The Alberta study presented at the meeting demonstrated an increase in hoary bat acoustic detections as well as reported fatalities between 2015 and 2016. This seems to contradict your findings. Do you think that incorporating more data in your analysis would suggest that wind energy mortality is not driving the species toward extinction?*

A: Not all sites we looked at saw a decline in fatalities from year one to year two (we saw a decline at 63.5% of the sites), but ON AVERAGE fatalities declined by 4 bats/turbine/yr. More data is always good, if the data are comparable between years. We believe that our data set is robust (especially given the very strong p value). The cause of the observed decline remains uncertain.

Q: *Were other sources of mortality (aside from wind energy) considered during this analysis? Similarly, does the assumed annual mortality rate of 128,469 bats account for new mitigation techniques and the implementation of the AWEA BMP in the US?*

A: We did not consider the AWEA BMP for the population modeling portion, but we also did not consider build out of more wind energy facilities, so we held per capita fatality rates constant.

Q: *Do you plan on running similar models for Eastern red and silver-haired bats?*

A: Eventually, yes.

Comment: *Lower mortality during the second year of a project could result from learning the location of the obstacle on a traditional route. Bats do not need to have had a near-fatal experience; might respond to the turbine as they would to a new building or cell tower.*

The Effects of a Wind Energy Development
on a Greater Sage-Grouse Population

Presenter: Chad LeBeau, Western EcoSystems Technology (WEST), Inc.

[presentation]

Authors: Chad LeBeau, Gregory Johnson (*Western EcoSystems Technology, Inc.*), Matthew Holloran (*Wyoming Wildlife Consultants, LLC*), Jeffrey Beck (*University of Wyoming*), Ryan Nielson, Mandy Kauffman (*Western EcoSystems Technology, Inc.*), Eli Rodemaker (*Image Spatial Consulting*), Trent McDonald (*Western EcoSystems Technology, Inc.*)

<u>PROBLEM / RESEARCH NEED</u>

Increases in wind energy development are especially noticeable in prairie habitats with high wind capacity. This has raised concerns over impacts to grouse species including greater sage-grouse (*Centrocercus urophasianus*), a complex species that require different habitat types during nesting, brood-rearing, and summer periods.

<u>Objectives</u>
The purpose of this study was to investigate the effect of wind energy infrastructure on sage-grouse habitat selection patterns and fitness parameters. This is the only investigation to date in the U.S. of the habitat selection and demography responses of sage-grouse to the infrastructure associated with a wind energy development.

<u>APPROACH</u>

The Seven Mile Hill Sage-Grouse study area is located in Carbon County in southeast Wyoming, north of Interstate 80 and south of the Medicine Bow River. The treatment area included 79 1.5-MW turbines which became operational in 2008, with the study starting in 2009 and continuing through 2014.

We captured and radio-marked a total of 346 female greater sage-grouse, attempting to include a representative number of females from all active leks within 16km of the turbines. Our control group consisted of 186 marked sage-grouse captured on leks south of U.S. 287, an average of 11 km from the nearest turbines. The treatment group consisted of 160 females captured at leks an average of 2 km from the nearest turbine. The defined boundaries for these study areas was based on the distribution of 346 radio-marked females. Grouse locations were recorded one to three times per week depending on the season.

Slide #5 shows the positions of the leks relative to the turbines and access roads. A total of 43 km of transmission lines also cross the study area, and had been present for more than ten years prior to wind energy development (26 km of transmission lines within the treatment area, 17 km within the control area). The slide also shows how ground cover covariates differed from 2009-2011 compared to 2012-2014.

We first ran univariate models to determine the most appropriate scale and reduce variables correlated with others, then built the best model based on environmental effects, looked to see if anthropogenic effects like major roads and transmission lines added any value, and finally looked at turbine effects. Model selection attempted to control for confounding factors prior to adding the effects of infrastructure.

<u>FINDINGS</u>

<u>Habitat selection</u>

Is facility displacing sage-grouse from suitable habitat? We developed a series of resource selection functions to estimate the relative probability of nest site selection, brood rearing and summer habitat selection relative to the wind energy facility.

- **Nest sites** - We did not detect a negative impact of the wind energy facility on nest site selection during the study period. We continue to see nest locations within the facility six years post-construction. Turbines do not seem to influence nest site selection. Slide #8 shows the final model covariates.

- **Brood rearing** – While we observed broods in close proximity to the turbines, when incorporate other habitat features – roads, turbine pads – we did see females choosing to rear their broods farther from these surface disturbances. We also detected a time lag effect where the magnitude of the percentage of surface disturbance associated with turbine pads and roads was greater after three years following development compared to the first three years immediately following the development. Slide #10 shows the final model covariates.

- **Summer habitat** – Females who did not successfully nest or were done rearing broods tended to select summer habitats away from the facility. Slide #13 shows the final model covariates for summer habitat selection.

We cannot compare the results of this study with other grouse studies because this was the first. But studies of prairie chickens display similar avoidance – not of nest sites, but of brood rearing and summer habitat choices impacted by the facility. Density of turbines was more important than proximity.

Survival

To look at survival, we combined all data and used Cox proportional hazards. Because sage grouse are lek-centric animals, we included the effect of leks as a random variable. We did not detect an effect of turbines on nest survival or brood rearing survival (slide #17).

Lek of capture turned out to be significant for brood survival. See slide #18: the lek labeled OC 31 was a "bad neighborhood" for broods, associated with high levels of brood failure, while OC35 was a really "good neighborhood." There is something going on the landscape relative to these leks that is affecting survival, but the covariates we used did not capture this variability.

Interestingly, females that chose summer habitat with higher density of turbines had higher survival (slide #19). This finding is similar to what has been found for greater prairie-chickens in Kansas, where adult female survival was higher near the facility post-construction. We are not sure what is driving this. Golden eagles and hawks are a main predation source; if these predators are avoiding turbine areas, this may be the reason for higher sage-grouse survival. We did do concurrent avian point count surveys, which suggested there were in fact fewer predatory birds nearer the turbine facility.

CONCLUSIONS / APPLICATIONS

The demography and spatial responses of greater sage-grouse in this study was similar to greater prairie-chicken responses to wind energy development, where turbines had no effect on nest survival, and a positive effect on female summer survival.

If we follow the annual cycle of the birds at the study area we saw that:

- Females were not greatly impacted by the turbines during the nesting period.

- As nests hatched, females moved away from leks and selected against habitats with lower density of turbines at the treatment area. Survival of broods was not impacted by turbines.

- As broods fledged and females began to group with each other we saw females selected against habitats with lower density of turbines at the treatment area. We saw no negative effect of turbines on female survival.

Future wind energy developments should consider the effects of wind energy development on sage-grouse habitat selection patterns and survival parameters. This type of analysis is critical in planning future wind energy development facilities that occur within occupied sage-grouse habitats. Based on our analysis, future wind energy developments located in similar habitats with a similar disturbance footprint to our facility (0.7% within 1.20 km of the facility) should consider the potential impacts of wind energy development on sage-grouse habitat selection patterns and survival parameters at least within 1.20 km from any occupied nesting, brood-rearing, or summer habitats.

Questions & Discussion

Q: *Could the negative effect of the turbines that you found on habitat selection be confounded by the proximity of the turbines to roads, or did you control for that?*

A: I didn't have time to get into the modeling methods, but yes, in our modeling, we considered different covariates of vegetation, transmission lines and roads in our model selection process. The first step was to estimate these environmental models that were the best fitting, and then add the effect of the facility and see if there was any improvement. Once we did find an effect we removed transmission lines, removed roads from the model to see if that changed the results. So we are confident that we limited the potential for confounding covariates.

Q: *Why do you think there was higher female survival within the wind facility?*

A: We hypothesize that it is because there are fewer avian predators; we saw a lower density of those predators in and around the facility.

Q: *Could avoidance of the wind farm lead to increased mortality of sage grouse due to displacement from more desirable habitat. Was this looked at, and if not, will it be?*

A: Avoidance was not a large shift, and because it wasn't a large shift, we don't think it affected survival.

<u>Additional questions not asked during the session Q&A</u>

Q: ***What about ravens, and how do you think turbine infrastructure developments may have on raven populations and what cumulative impact on grouse?***

A: Anthropogenic landscape features appear to increase raven densities and I imagine turbine infrastructure could do the same. Increases in raven populations can negatively affect sage-grouse populations; however, certain measures can be initiated to reduce this threat such as trash removal for example.

Q: ***Did you survey for mammalian predators? Some new research from Wyoming indicates that mammals are equal or greater predator impacts than avian predators. What do you think are the impacts form wind facilities on mammalian predation (increase in predators)?***

A: We did not survey for mammalian predators. There could be an increase in predators (edge effects) but we did not detect an increase in predation as a result of the facility.

<u>Question for all panelists:</u>

Q: ***Thinking 10-15 years ahead and there are 3 times the number of wind turbines on the landscape, and no additional mitigation than what we know about today – what do you anticipate as the impact on animals?***

Martin: I don't see major negative effects on pronghorn. This is a resident population, so some seasonal shifts but no migration, so not as big an effect.

Erin: it depends what the starting population is and population growth. If it's what we think it is, I would anticipate a decline of about 50%. If the starting population is smaller or growth is smaller, it could go to zero 20 years out.

Chad: Sage-grouse was up for listing, but U.S. FWS determined that there are enough conservation measures out there now.

Furthering Understanding of Siting and Assessment

Moderator: Amanda Hale, Texas Christian University

Avian Mortality at Three Wind Energy Facilities
on the Gulf Coast of Texas

Presenter: Elizabeth Baumgartner, Western EcoSystems Technology (WEST), Inc.

Authors: Wallace Erickson, Victoria Poulton, Elizabeth Baumgartner, Kimberly Bay, Gregory Johnson (*Western EcoSystems Technology, Inc.*), Jerry Roppe (*Avangrid Renewables*), Rene Braud (*Pattern Energy*)

PROBLEM / RESEARCH NEED

Three utility-scale wind energy facilities – Pattern Energy Gulf Wind Project and Avangrid Renewables Peñascal I and II Wind Projects – were built adjacent to each other along the Lower Gulf Coast of Texas on the coastal sand plains west of the Laguna Madre. The unique ecology of the Texas Gulf Coast suggested the potential for adverse impacts to birds, particularly migrating songbirds and waterfowl, as a result of developing and operating these facilities. In recognition of these concerns, multiple years of post-construction monitoring were conducted to estimate bird mortality at these facilities.

Objectives

This presentation describes the ecological context of these projects, characterize the post-construction monitoring effort and results, and compare those results with mortality at inland wind energy projects.

CONTEXT & APPROACH

The Gulf Coast of Texas is an attractive wind development area because of the steady energy resource coupled with demand nearby. The Gulf Wind & Peñascal Wind projects are bordered on three sides by ecologically unique features:

- ***Laguna Madre,*** which borders the projects to the east, is a hypersaline lagoon. Its salty, warm, shallow water facilitates a diverse community of aquatic vegetation, fishes, mollusks, and crustaceans, providing year-round foraging habitat for aquatic birds.

- **Saltillo Flats**, to the south, is a 20-mile long land bridge dividing the North and South Laguna Madre. These sporadically inundated tidal flats of sand and mud provide habitat for birds that forage on insects and crustaceans buried in the mud.

- **Baffin Bay** is important for aquatic birds and buffers the projects for species such as raptors that avoid migrating over water.

Of particular interest prior to construction was waterfowl movements in relation to the planned project. Redheads were of particular concern when developing the projects, as nearly 80% of the North American population of redheads winters in the Laguna Madre area along the Gulf of Mexico in Texas and Mexico. Redheads forage almost exclusively in the Laguna Madre and primarily on shoal-grass rhizomes; however, they make frequent flights to adjacent coastal freshwater ponds to dilute salt loads ingested while foraging. (Ballard et al. 2010). Pre-construction surveys examined waterfowl movement in the area, using many hours of visual observations as well as radar, and the projects were sited to avoid areas of concentrated waterfowl movement.

The southern Gulf Coast of Texas is a high migration area; the consistent sea breezes that make wind energy development along the Gulf Coast feasible also facilitate reliable lift for birds. Three major fall migratory bird pathways converging just north of Corpus Christi and many species using the gulf coast as stopover habitat while tracking along the coast to reach wintering sites in Mexico/Central and South America. As well, certain weather conditions may force trans-Gulf passerine migrants to land on the Texas Gulf Coast. Passerines prefer to land in the floodplains or forested wetlands further inland when possible, as these areas provide more suitable stopover habitat.

We compiled data on species potentially breeding in the area surrounding the projects from USGS Breeding Bird Survey data from 1966-2013 (101-119 species). Christmas Bird Counts data for the years 2011-2016 from Corpus Christi (Flour Bluff), Kingsville, and Kenedy County Wind Turbines were as high as 184 wintering bird species, though the maximum count of wintering bird species was 101 species at the Kenedy County Wind Turbines survey point.

Post-construction mortality monitoring was conducted at the Gulf Wind and Peñascal I & II facilities from 2009 to 2011 (Gulf Wind) and to 2012 (Peñascal). At each project, 16 turbines were monitored at 8-day intervals and another 14 turbines monitored daily during spring (March 15 - May 15) and fall (August 15 - October 15). A total of 1449 surveys were conducted at 8 day intervals and over 3,000 daily searches at Gulf Wind, and 2,181 8-day searches and 4,464 daily searches at Peñascal.

Searcher efficiency and carcass persistence trial data were combined for all three sites for years 1 and 2, and gathered for the Peñascal sites only during year 3. Searcher efficiency ranged from 54 to 83% for large birds, and from 35 to 46% for small birds. Carcass removal times for large birds ranged from 12 to 47 days and for small birds from 5 to 15 days, depending on the season.

We compared both the species composition and mortality at the Gulf Coast projects with composite data from North American wind energy facilities.

FINDINGS

Yellow-breasted chat and red-eyed vireo were most common passerine fatalities found. 84.2% of the yellow-breasted chat (16 of 19) fatalities found at Peñascal during Year 1 were found in a single week at the end of April, following the passage of a weather system that produced persistent precipitation between April 7 and 23. Common non-passerine species were mourning dove (the seventh most common North American bird fatality) and turkey vultures, which are more commonly found in Texas than elsewhere. The most common raptor species was American kestrel (12 fatalities). Fatalities included relatively few soaring birds (buteos), likely due to the buffering effect of Baffin Bay. Species composition was compared with what has been found at 212 other North American wind energy facilities, for all birds and specifically for aquatic birds.

The maximum number of bird fatalities observed on any day at any one turbine was 4 carcasses (Peñascal August 2010); otherwise, the maximum was 2 birds. Among 151 comparable studies, Gulf Wind and Peñascal were well within the range of North American fatality rates:
- 4.91 birds/MW/year at Gulf Wind
- 5.02 birds/MW/year at Peñascal
- 0.08-17.44 fatalities/MW/year at 151 post-construction monitoring studies across North America

Diurnal raptor fatality estimates showed limited fatality and limited species composition (2 - 5 unique species annually) – again, well within the range of what we see across North America:
- 0.16 raptors/MW/year at Gulf Wind
- 0.15 raptors/MW/year at Peñascal
- 0 – 1.06 raptor fatalities/MW/year at 138 Wind energy facilities across North America

CONCLUSIONS / APPLICATIONS

Despite substantial concern that wind energy development along the Gulf Coast of Texas might lead to high levels of avian mortality, estimated total avian and diurnal raptor fatality rates at the Facilities were comparable to fatality estimates at other wind energy facilities in North America. This is likely due to avoidance behavior and migration flight behavior, as well as the lack of an attractant, such as steady-on lighting. The avian species composition of carcasses reflected the coastal location of these projects, with a larger diversity of aquatic bird species found over the entire study compared to the species composition of carcasses found at upland facilities across North America. Nocturnal migrant bird fatalities tended to be found in higher numbers following precipitation events, particularly in spring; however, no more than 4 birds were discovered at one turbine during the five years of study at the Facilities.

Questions & Discussion

Q: *What do you think are the reasons for high yellow-breasted chat mortality at this project, considering it is one of many migratory passerines moving through the area but is not typically found?*

A: We found 33 fatalities, and we saw an interesting pattern – especially in 2010, a very wet, rainy year – 16 of the 19 chat fatalities found at Peñascal in 2010 were found in one week following the passage of a weather system that produced persistent precipitation.

Q: *Did you observe a larger number of redheads at the Texas projects compared to other projects in your dataset? Did redhead behavior or habitat use change post-construction?*

A: We did not document any redhead fatalities. Our study was designed to estimate mortality; therefore we did not quantify behavior/use post-construction.

Q: *What percentage of turbines were surveyed at Gulf Wind and Peñescal and how were they selected?*

A: Random systematic selection. We searched approximately 25% of turbines at Gulf Wind, and approximately 18% of turbines at Peñascal I and II.

Q: *What were the bat mortality rates for the Gulf Coast post-construction studies?*

A: While we collected data on bat mortality, those data were not included in the manuscript associated with this presentation.

Q: *In summarizing avian mortality, why not include a total for "bird species of conservation concern"?*

A: The concern prior to construction was mostly with waterfowl and migratory passerines, which is why they were the focus of this manuscript.

Additional questions not asked during session Q&A:

Q: *How did you account for animals falling outside your search plots or at unsearched turbines?*

A: We calculated an area correction using the Hull and Muir (2010) method. Fatality estimates are reported on a per MW basis, which provides a standardized rate for the facilities. In the first year, biologists were on site daily (except Thanksgiving and Christmas), with the objective of detecting any large mortality events. Biologists would travel the sites scanning for evidence of avian and bat carcasses and would perform abbreviated searches at select turbines, which were in part influenced by the biologists' assessment of the overall environment that day. The finds documented during these searches are included in the overall count of carcasses provided; however, these data are not included in the fatality estimates as searcher efficiency trials were impractical due to the objective and subjective manner of turbine search selection.

Q: *Would you say your fatality monitoring was robust?*

A: The fatality monitoring study design was appropriate to meet the objectives of the study.

Challenges in Quantifying the Effectiveness of Impact Avoidance and Minimization Measures and Potential Solutions

Presenter: Julie Garvin, Tetra Tech

[presentation]

Authors: Julie Garvin, Thomas Snetsinger (*Tetra Tech*)

PROBLEM / RESEARCH NEED

There are numerous challenges to estimating the effectiveness of impact avoidance and minimization measures at reducing bird and bat fatalities at operational wind facilities.

It can be hard to implement an experimental design at an operating facility. For example, one cannot reserve part of the facility as a control group if the measure is required facility-wide, and if a facility is small, there may not be enough statistical power to demonstrate effectiveness. Other challenges may include a poor understanding of factors related to risk/impacts; difficulty in controlling for confounding factors, and the inherent uncertainties in fatality estimation.

Collision mortality may be categorized according to whether the fatality events in question are frequent, or whether they are rare, as in the case of eagles or endangered species. The latter category poses its own specific set of challenges because of the difficulty of detecting the occurrence of rare events, and the inherent uncertainty of fatality estimation when events are rare. This uncertainty leads to large confidence intervals which can obscure any potential reductions in fatalities realized by the implementation of avoidance and minimization measures.

Objectives

The objective of our study is to review these challenges using illustrative case studies, and to provide potential solutions. We draw upon our experience working with numerous wind energy facility owners and operators across the country as well as published information in both peer-reviewed and gray literature.

APPROACH

Whether fatality events are frequent or rare, we need to be able to monitor and quantify the reduction of impacts to measure or demonstrate the effectiveness of minimization measures. The estimated or observed fatality rate for the target species is the most common metric used to assess minimization measure effectiveness, but it may lack precision or may not accurately capture risk (for example, if animals are crippled in a collision but die outside the monitoring area). In some instances, an alternative metric to fatality rates may be more appropriate to quantify effectiveness of a given minimization measure. Suitable alternative metrics are those that are well-correlated with risk, can be measured with relative accuracy, have good sample sizes, and have baseline data available. Correlation with risk can be the trickiest attribute to satisfy.

FINDINGS

Measurements of use or other behavioral variables are one alternative to fatality rates. If the focal species is rare or endangered, another alternative may be to estimate fatality rates or behavioral responses for a more common surrogate species.

Behavioral responses

Example 1: Hypothetical use of audible deterrent for raptors – flight paths or use (e.g., birds observed/hour) in the zone of risk can be quantified and are often collected pre-construction, providing a baseline. Use or flight paths in the zone of risk are assumed to be correlated with collision; probabilities are available in the literature. Response to initiation of the deterrent can be measured, with averted flight paths equated to avoided collision risk.

Example 2: Actual study investigating using dim UV light as a deterrent to Hawaiian hoary bats at a Macadamia nut plantation. Bat use (e.g., bat passes/night) is potentially correlated with collision risk. Effectiveness of dim UV light deterrent installed at macadamia nut orchard was tested using thermal and acoustic detectors to quantify bat use, pre- and post-implementation. Bat use was greatly reduced with the UV light treatment.

Surrogate species

Surrogate species must meet several criteria to be a good fit for the purpose, including similar behavior patterns with respect to risk. Sandhill cranes are a common species that could serve well as a surrogate for endangered whooping cranes.

Rare events

Rare events have their own unique challenges – they often are tied to regulatory risk and a greater level of monitoring effort is generally required, both to demonstrate permit compliance and to provide a statistically robust assessment of minimization measure effectiveness.

<u>CONCLUSIONS / APPLICATIONS</u>

Study design is crucial, and effectiveness monitoring needs to be considered at the earliest planning stages. The results of effectiveness monitoring will influence whether agencies accept an experimental avoidance measure. Similarly, the effectiveness of a given measure will influence whether or not additional measures are needed in order to adaptively manage impacts. Lastly, reductions in impacts demonstrated through effectiveness monitoring may influence future compensatory mitigation requirements.

By successfully addressing these challenges, estimation of fatality rates should improve, and the effectiveness of avoidance and minimization measures should be better quantified. Having a suite of avoidance and minimization measures that have been verified to be effective will improve permit compliance and better enable adaptive management of impacts at operational wind facilities.

Remember: *If you didn't measure it, it didn't happen!*

Questions & Discussion

Q: *Why would migratory birds be listed as a voluntary reason for minimization, given the Migratory Bird Treaty Act (MBTA)?*

A: Current regulations do not require that you do avoidance/minimization; avoidance and minimization measures are recommended as due diligence standard for migratory birds even at siting level.

Q: *You mentioned "if you show effectiveness that resulted in fewer eagles than expected, then you might get a mitigation credit" – can you elaborate?*

A: Some regulatory constructs, for example eagle take permits, allow for a periodic balancing of mitigation credits and debits. In order to receive a mitigation credit, you need to demonstrate that you had less take than the predicted amount. How to do this depends on the fatality monitoring study design and statistical rigor, and on how take prediction and fatality estimates are being calculated. The methods used to predict take are designed to allow for updating with post-construction fatality monitoring data. The updated prediction can be used to determine whether or not you met or exceeded your take limit. If you did not meet your take limit, you could be eligible for a mitigation credit. Typically, this would be applied under a permit renewal.

Q: *You mentioned the importance of measuring the effectiveness of avoidance/minimization measures. Is this possible for siting? Can you give examples?*

A: We would need to come up with some alternative metrics, for example using breeding bird survey data – what is here, and what do we think the fatalities could be based on existing fatality data? Then we would need to compare those metrics with a similar analysis for our revised location. We would consider the difference to be the reduction if we avoided siting in

the first area. In general, quantification of the reduced impacts as a result of avoidance is difficult, and the benefits from quantifying the reduction may be relatively minor. However, it is important to document avoidance and minimization efforts such as siting outside of core habitats as these are important elements in regulatory and environmental review documents.

Managing Wind Farms – What is the Role of Adaptive Management?

Presenter: Andrea Copping, Pacific Northwest National Laboratory

[presentation]

Authors: Andrea Copping, Luke Hanna (*Pacific Northwest National Laboratory*)

PROBLEM / RESEARCH NEED

Both land-based and offshore wind energy face controversy over potential threats to birds and bats. The scale of threats do not match the scale of wind farms, but permitting decisions are made at single farm level, and we need tools to bridge that gap. Adaptive management (AM) is a systematic process intended to improve policies and practices by learning from the outcome of management decisions. Could adaptive management (AM) provide some insight and relief?

The international collaboration WREN (Working Together to Resolve Environmental Effects of Wind Energy) under the IEA Wind Committee identified the application of adaptive management principles and practices as an important aspect for improving planning, monitoring, and management of wind farms in the United States and internationally.

Many nations are considering the use of AM to balance promoting the development of the wind energy industry with significant uncertainty concerning environmental effects. However, application in policy and in practice has been limited. Recent application of AM has led to fundamental differences in the definition of AM, its application, and to which projects or planning processes it might apply.

Objectives
WREN's first white paper suggests a common definition and framework for AM, based on the U.S. Department of the Interior's AM definition and guidance. Our objective is to try to reduce uncertainty, and disseminate what we do know.

The process of defining and applying adaptive management (AM) to land-based and offshore wind farms was examined and examples gathered of the use of the system from the U.S. and European countries. AM is often described as "learning by doing." It is a systematic process of practice and principles to assess a problem, design a solution, implement, monitor, evaluate, make adjustments, and re-assess. At a single wind farm, the process can be diagrammed as a single loop. At a larger scale, the process follows a double loop, where the evaluation and learning problem informs both policy and planning for future projects and management practices at existing projects.

An adaptive management approach requires data collection that is driven by a specific hypothesis. There must be both a need and the possibility of decreasing scientific uncertainty. The "learning loop" involves producing good predictive models, validating them, improving them, validating them. The results must be sufficient to drive/improve a predictive model. These principles are essential to data collection that avoids the "DRIP" problem: Data Rich, Information Poor.

Outcomes are also part of the adaptive management cycle. The project must be structured to allow for changes in management. If the operations are too hemmed in by regulations, there is no point to an adaptive management approach.

FINDINGS

United States

There are relatively few AM plans in use in the United States. We examined 16 plans, most of which focus on federally protected species, and surveyed a dozen practitioners. We found a lack of consensus about both the concept and practices, and differing opinions about whether:
- AM at the single wind farm level is "real AM"
- Data collection needs to be hypothesis-based
- The adaptability aspect of AM makes it useful

Implementation tools are limited. Mitigation measures vary, from approaches that set predetermined limits or boundaries to those that apply a more flexible approach. Different wind developers have differing appetites for risk, but developers agree that financial risk associated with uncertainty is a key concern for use of adaptive management.

Other WREN countries

There is limited legislation applicable to adaptive management in most nations, and no formal regulations found in any of nine non-U.S. WREN countries for the use of AM for wind energy permitting. At the same time, several countries are using conceptual attributes of AM to regulate wind energy development. For example:

- **Portugal** – in response to high kestrel fatalities found at a wind farm where the monitoring program was not intended to focus on kestrels, a site-specific mitigation program was developed in cooperation with developers and regulators.

- **Norway** – at the Smøla wind farm, Statkraft supported research to examine the effectiveness of mitigation measures for white-tailed eagles (*Haliaeetus albicilla*), decreasing uncertainty.

- **Netherlands** – AM principles were used to adapt construction and monitoring at an offshore wind farm (bat detectors added, modeling effects of pile driving on harbor porpoise and studies on the effects of piling noise on juvenile fish and larvae). The Netherlands plans to apply AM principles to ten offshore wind farms.

- **Germany** – a wind farm in southwest Germany curtailed turbine operation to protect bats, and adjusted curtailment methods after a year, and a project in northern Germany curtails turbine operations to mitigate for collision risk to red kites.

- **Switzerland** – expansion of a high altitude wind farm is on hold until bird and bat impacts are better understood. Monitoring data have been used to set curtailment requirements, which differ seasonally, and a stakeholder group determines curtailment needs and reassesses project operation annually.

- **Spain** – In response to high mortality rates for Griffon vultures in southern Spain, a program was established to monitor birds in flight, stop turbines when birds approached the risk zone, and then restart turbines after birds are gone. After two years, bird mortality was decreased by 50%, with only a 0.7% loss of energy production.

CONCLUSIONS / APPLICATIONS

Adaptive management is most useful at a scale larger than a single wind farm. If we can pool data over a larger region and examine effects on migratory populations, we would learn a lot over appropriate time scales. AM can also be useful on the scale of a single wind farm. While any data collection for permitting at a single wind farm is the responsibility of the developer/operator, it does not seem reasonable to expect one developer to bear the financial risk burden for data collection that will result in application of AM over wide geographic areas and time scales. It would be better to encourage standardized collection of data across projects.

The WREN white paper recommends improvements that could be made to AM guidance including:

- Adoption of a universal definition of adaptive management, coupled with an agreed-upon set of eligibility criteria;

- Careful consideration to the optimal spatial and temporal scales for wind energy AM that can be meaningfully informed by reducing scientific uncertainty. For example, AM may be applied to a single project but is more likely to be useful applied at a larger scale to inform planning for future projects;

- Careful application of AM to wind energy is needed to ensure that it does not interfere with project financing models or harm resources protected by each nation;

- Formal processes and structures are needed within regulatory bodies for the use of environmental impact data from existing projects in order to create learning and useful application to future projects.

This white paper is available on [WREN website](#),[2] as well as longer version of this talk in form of [webinar](#)[3] done by Andrea Copping and Finlay Bennet.

Questions & Discussion

Q: *Does there need to be a hypothesis bird data are being collected to address?*

A: You need to base your data collection on a hypothesis in case of adaptive management, but also good to do that even if not using AM.

Q: *WREN white paper – was there formal or informal peer review? If so, what mix of stakeholders and industry participated in the review?*

A: The paper, which included several DOE authors, went through peer review, and it went out to broad range of stakeholders (66 people invited, of whom 14 responded), including some who had been interviewed for their comments. DOE, FWS, NOAA, BOEM also had an opportunity to review.

Q: *Small sample sizes hamper the evaluation of effectiveness; how do we get around that?*

A: If you don't have enough data within a single project for statistical significance, there's not much to do about that. That's why adaptive management is not a panacea, and it is not always applicable at a project scale.

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[2] https://tethys.pnnl.gov/publications/assessing-environmental-effects-wren-white-paper-adaptive-management-wind-energy

[3] https://tethys.pnnl.gov/events/adaptive-management-wind-energy-industry

Endangered Species Risk and Impact Estimation

Moderator: Corey Duberstein, Pacific Northwest National Laboratory

Flight Response to Topographic, Vegetative, and Temporal Correlates Predicts Risk from Wind Turbines to an Obligate-Soaring Bird, the California Condor

Presenter: Sharon Poessel, U.S. Geological Survey

Co-Authors: Sharon Poessel (*U.S. Geological Survey*), Joseph Brandt, Laura Mendenhall (*U.S. Fish and Wildlife Service)*, Melissa Braham (*West Virginia University*), Michael Lanzone, Andrew McGann (*Cellular Tracking Technologies LLC*), Todd Katzner (*U.S. Geological Survey*)

PROBLEM / RESEARCH NEED

Wind power is a fast-growing energy source in the United States, and the state of California is a national leader in wind energy development. However, the flight behavior of soaring birds may place them at risk of collision with wind turbines. Critically-endangered California condors (*Gymnogyps californianus*) in particular are obligate-soaring birds with high wing-loading and low maneuverability, which puts them at greater risk of collision. Condors use both thermal and orographic updrafts. While no condors have yet been killed by turbines, the concern is increasing as the birds are successfully re-introduced and as wind energy development increases in California.

Objectives

The objectives of our research were:

1. To evaluate patterns in individual-specific flight responses of condors to topographic, vegetative, and temporal variation in their environment, and
2. To evaluate this flight behavior in the context of distance to wind resources and proportion of time spent within the rotor swept zone (RSZ – 50-150 m above ground-level) where there is potential risk from collision with turbine blades.

We hypothesized that condors would vary their flight altitude with spatially-, temporally-, and sex-specific responses to topography and land cover, and that risk from wind energy development would vary seasonally.

APPROACH

From late fall 2013 to summer 2015, we captured 14 female and 10 male condors between the ages of one and 33 years at two National Wildlife Refuges (Hopper Mountain and Bitter Creek) in Southern California. We tagged them with GPS-GSM patagial telemetry units, and then analyzed altitudinal data from about 103,000 flight locations collected between December 2013 and November 2015. Flight locations were mapped between the two wildlife refuges and east to the edge of the Tehachapi Wind Resource Area, north up into Tulare County, and west and northwest into Monterey County.

To achieve our first objective we examined the types of terrain and land cover over which condors flew by obtaining three external variables.

1. Topographic Position Index (TPI): valleys, lower slopes, gentle slopes, steep slopes, upper slopes, ridges

2. Terrain Ruggedness Index (TRI): a measure of landscape roughness

3. Land Cover: Forest, shrub/grass, semi-desert, sparse rock vegetation, agriculture, developed, open water

We then modeled variation in flight altitude (response variable), with sex, age, hour, month, TPI, TRI and land cover as predictor variables.

To achieve our second objective, we obtained wind class info from NREL and calculated distances from flight locations to high class winds and the proportion of flight locations that were within or below the rotor-swept zone of wind turbines.

FINDINGS

Our as yet unpublished results indicate that condor flight behavior was strongly influenced by topography and land cover. Condors fly highest when foraging over flatter, more open landscapes, i.e., over valleys, gentle slopes, open water, and agriculture. These birds fly at lower altitudes when over ridge lines and over forested, grassland, and sparse cover types.

Condor flight behavior also was strongly cyclical, in ways that correspond to their dependence on thermal and orographic lift. The top model showed that condors take advantage of thermals by flying high when thermals are strongest during mid-day and summer, and that they fly lower during early morning and evening hours and during the winter months, when thermal updrafts are weakest. Condors roost at night in the mountains, and they fly at lower altitudes over rougher terrain as they fly to and from their roost sites, making use of orographic updrafts during the early mornings/evenings.

We did find that males fly higher (most likely because they are about 4% larger, and therefore have higher risk of grounding) than females.

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Condors regularly flew near or within wind resources preferred by energy developers. A majority of condor locations – 58% – were within 500 meters of areas with high class winds and 28% of locations were within areas of high-class winds (i.e., distance of zero). Although the majority of flight locations were above the rotor swept zone of wind turbines, 37% of all locations were ≤150 m AGL. However, distance from high-class winds was not related to flight altitude.

CONCLUSIONS / APPLICATIONS

The strong response of condors to variation in the spatial and temporal updraft environment they experience provides insight into risk management for this species. Our analyses indicate that this risk should vary seasonally and may be greatest when condors fly over areas with high topographic relief.

Condors regularly fly near winds required by energy developers, with flight altitude strongly responding to thermal updrafts, especially during the daytime and in the summer. Use of orographic updrafts early and late in the day (and winter) pose the greatest threat.

Developers and permitting agencies should consider spatial and temporal patterns of flight when siting turbines, avoiding placement near locations where they fly at lower altitudes, such as near their nocturnal roosting sites or in areas of high topographic relief. In contrast, risk should be relatively lower when condors fly over less rough areas and from turbines placed in habitat they use during daytime soaring. Although the condors we studied were from the southern California population, our results should be applicable throughout their range. Development planners can incorporate knowledge about the flight behaviors of condors to reduce the potential for wind-wildlife conflicts.

Questions & Discussion

Q: *Why would condors fly higher over water?*

A: They may just be traveling high because they know there is no food there, and also to avoid grounding, risk of drowning. (***What is "grounding"?*** A: Condors don't usually flap, just soar. If they run out of thermals, they could just fall to the ground.)

Q: *How would you use your findings to inform curtailment strategies for wind turbines?*

A: Our data show that to prevent risk to condors, turbines should not be sited in those locations where condors fly at lower altitudes. For existing turbines, the geo-fence technology looks promising. Curtailment based on real-time detection of condors within the wind farm.

Q: *Did you see any difference in flight height by age?*

A: We did not see any difference in flight height based on age. Note, however, that we did not have any hatch-year birds in our data analysis; if we did, we might have seen an age difference since these very young birds may have different flight behaviors than older birds.

Q: *How close did you observe condors coming to operating wind turbines?*

A: For the data we used for this study, flight locations came up to edge of wind farm, but none of them went inside it. Those data ended in November 2015. Since then, condors have been flying inside the footprint of a wind farm but no collisions have occurred.

Q: *Given that condors are opportunistic foragers, would you anticipate increased risk from carcasses in vicinity of turbines?*

A: Condors do feed on carcasses, but usually larger ungulates, not birds that might collide with turbines. Although it is possible that they might feed on birds that have died from turbine collision, it is not very likely.

Publication? We have submitted our paper to Plos One for publication consideration.

Additional questions not addressed during session Q&A

Q: *Might your flight height estimate be biased high by only including flights >100m when the animal is flying slowly?*

A: We used a high cutoff (100 m) because the terrain in southern California is quite rugged with tall trees and high cliffs. If we had used a lower altitude for those locations with speeds <3 knots, we may have erroneously included locations where the bird was perching in a tree or on a cliff. We chose to be more conservative to ensure that we did not include such perching locations in our flight locations. Even with this cutoff, 1/4 of our flight locations were still <100 m, so we do not believe that our flight altitudes were biased high.

Q: *Could you turn your bar graph into a stacked bar graph to show how much of the condor flight near the wind area is associated with each of the wind classes? I suspect based on the flight data that most of it is near class 3 winds.*

A: We could do this, but for this study we did not break out flight locations among each of the wind classes; we combined all classes >=3 and reported the distances to these combined winds. If someone would like this information (i.e., distances to each of the wind classes separately), we would be happy to provide it.

Q: *Can the condor population sustain estimated levels of predicted take (going up to Tier 8)?*

A: Due to the many other threats to condors, especially the continuing mortalities from lead poisoning, the condor population cannot withstand any additional mortalities from wind turbine collisions.

Spring Migration of Indiana Bats (*Myotis sodalis*) and What It Means for the Wind Industry

Presenter: Piper Roby, Copperhead Environmental Consulting, Inc.

[presentation]

Co-Authors: Piper Roby & Mark Gumbert (Copperhead Environmental Consulting, Inc.)

PROBLEM / RESEARCH NEED

The Indiana bat has been federally endangered for almost 50 years, yet there are still important information gaps in the species life history. We know that it hibernates in caves during winter and roosts in trees in the summer. A small bat weighing 5-8 g, the Indiana bat is considered a regional migrant [Slide #2], typically traveling less than 500 km between hibernacula and the locations of summer maternity colonies. Most of the migration information we have for Indiana bats comes from band recoveries, which give us only a starting and an ending point and the distance between them, but nothing about their behavior between those points. As wind energy development moves into the eastern United States, a better understanding of these patterns is critical to avoiding take of Indiana bats.

Objectives

We set out to test several hypotheses about Indiana bats' spring migration patterns:
- How long does the migration take?
- Do the bats fly throughout the whole night?
- How fast do they fly?
- Do they forage along the way?
- Do they fly in a straight line between habitats?
- How does weather affect them?

We hypothesized that bats would migrate north, require foraging stopovers during migration flight, and be negatively affected by inclement weather.

APPROACH

We partnered with state and federal agencies in Tennessee and Indiana to learn where hibernating bats in each state were summering, with the intention of locating previously unknown maternity colonies. From 2009 to 2016, we collected and radio-tagged female Indiana bats from known hibernacula in early April of each year, and then actively tracked them using aerial and ground tracking techniques. The bats were fitted with temperature-sensitive transmitters that recorded the temperature of the bat. Ambient air temperature was recorded

with a temperature data logger (iButton©) that was affixed to the roof of a truck or near an occupied bat roost.

We collected individual location points throughout the night while the bats were active to determine the direction migrated, the duration and speed of nightly flights and the overall migration journey, data about foraging areas, and activity correlated with ambient weather. Location points were tracked from an airplane, with ground support when needed, enabling us to locate diurnal roosts and identify maternity grounds.

We radio-tagged 236 bats from 2009 – 2016 but collected migration data on 11 individuals with an average of 308 location points per bat. The remaining bats were intended to be searched for on the landscape after they arrived at their summer grounds. We did successfully locate many bats after they arrived, but only collected migration behavior data on 11 individuals.

FINDINGS

We documented connections from five caves to 16 maternity colonies in six states, 14 of which were newly discovered summer colonies. The shortest distance between a cave and its corresponding colony was 6.2 km, from a hibernaculum in Tennessee to a maternity colony just across the border in Kentucky. The longest was 368 km, from a hibernaculum in Tennessee to a colony in Mississippi. Maternity colonies were often located in national forest land.

Over the years, we have been able to track several migrating Indiana bats to the same maternity colonies, providing information about migration corridors for this species [Slide #13]. Based on studies where bands placed on bats in their maternity ranges are recovered from hibernacula in the core of the Indiana bat range, bats are migrating south to north in spring [Slide #28]. But in the northeastern part of this range, they are more likely to be migrating south, and not traveling as far from their hibernation caves to their summer grounds. Only a few of the bats we tracked in this study in the southern portion of the range migrated north; most traveled west [Slide #11].

On average, it took bats about three nights (with a range of 1 - 5 nights) of active flight to arrive at their summer grounds. However, the average duration of the entire migration journey was a little over five nights (range of 1 - 16 nights). This discrepancy was due in part to the overall distance bats were traveling (an average of 163 km, range of 5.8 - 368.1 km) and the nightly speed, which averaged (an average of 9.4 km/hour, range of 0.7 - 19 km/hour). During spring migration, bats are coming out of hibernation, so they need to eat to regain energy. When we examine individual bat tracks more closely we see a lot of zig-zagging, indicative of foraging bouts, especially in the first day or two after the bat emerges from hibernation [Slide #19].

However, the chief cause for extended layovers during the migration journey was weather-related, due to cold temperatures or significant rain during the night. Only 0.5% of active bat temps occurred when ambient < 10°C (9 ambient temperature data points out of 1,641).

We identified many stopover locations for the 11 bats, but one stopover in particular was a protected bowl formation in Georgia [Slide #23] where two bats in two different years each stopped for 4 days – either emerging to forage or not at all. We looked at bat temperature as well as ambient temperature. A low bat temperature indicates that the bat is in torpor. In some cases we could tell from an abrupt increase in the bat's body temperature that it had awakened, but then went back into torpor because the ambient temp was less than 10°C [Slide #25].

CONCLUSIONS / APPLICATIONS

Although bat activity in general has been observed at lower temperatures for other species and other regions, spring migrating Indiana bats may not have built up the physiological resources necessary to withstand colder temperatures during this time of year, and thus enter into torpor when ambient temperature drops below 10°C to conserve energy. Therefore, wind turbine curtailment may not be necessary when ambient air temperatures drop below this minimum migration temperature.

Based on multiple bats tracked to the same summer grounds over multiple years, we can conclude that bats fly a pretty straight path from hibernacula to summer grounds. This knowledge should be used to guide siting decisions. It would be reasonable to map known straight-line connections between hibernacula and summer grounds, with a buffer of 35 km.

Conservation measures could also be implemented for the habitat used by migrating Indiana bats. Landscape analysis of areas used by foraging bats could be utilized in conservation measures as well.

Although we are starting to understand how Indiana bats move across the landscape, additional studies in other regions would help to supplement these data. We hypothesize that bats are flying faster during the autumn migration, but we need to do the same kind of analysis of behavior for this period, which is highest time for turbine mortality.

Questions & Discussion

Q: *What other weather indicators (precipitation, barometric pressure, etc.) might be affecting the bats' migration? Did ambient temperatures take into account "feels like" temperature variables (i.e., "wind chill" factor)?*

A: We started to look at barometric pressure. Mostly we looked at temperature with precipitation, but I would expect barometric pressure to correlate with precipitation. We did not account for relative humidity or wind chill, just ambient temperature, collected with iButton© (temperature data logger).

Q: *Can you speak to transmitter retention and how that might have affected your study?*

A: Because we start the tracking in early to mid-April, the transmitter battery dies before May 15th. This is the USFWS definition of the start of the maternity season, so we don't call the areas where the bats end up maternity areas. Several states have assumed that these tracking end-points are maternity colonies and have designated them as such.

Q: *What happened to tagged bats not included in analysis?*

A: At the beginning, were not able to track bats all the way to summer colony. Now have biologist pilots on staff who would stay with the bat all the way to summer ground. (More a function of pilot limitations than bats.) Sometimes when we knew of maternity roost, we would pick those bats up and collect the data at summer ground. Many other bats radio-tagged were located in their maternity colonies but were not actively tracked from their hibernacula.

Q: *Might tagging have influenced the destination, speed or range of the bats you tracked?*

A: We stayed within 5% rule (weight of transmitter: weight of animal) – did not always put transmitters on same bats, but we did catch several individuals more than once over multiple years. There did not seem to be any ill effect of the transmitters on bats.

Q: *How do you know when they have reached summer grounds?*

A: If weather was good and bat wasn't going anywhere, we considered this an indication it had reached summer ground. Once the bat reaches its summer ground, it is roosting with other bats (forming maternity colony).

Publication? Yes, but not any time soon.

Additional questions not addressed during session Q&A

Q: *Were the migrating Indiana bats following landscape features, such as ridge lines or river corridors?*

A: We have anecdotal evidence of that and have analyzed movement for a few bats, but not all. They seem to follow landscape features when the features are along the way the bat is going. The overall landscape seemed to influence this: in Indiana where there are a lot of agricultural fields, bats tended to follow riparian areas, but did travel very quickly across open fields to get to another stream going in the direction it was traveling. In Tennessee, several bats followed a long, wide valley for several kilometers, but eventually popped up on the ridge for a bit before abandoning that feature due to the direction the bat needed to go to get to its summer grounds.

Q: *What are some of the common landscape features along the migration routes? Would it be possible to conduct habitat analysis of the migration routes, and what do you think we would find? (For example, are there characteristics of the bowl formation in Georgia that might be used to identify other potential stopover locations for migrating Indiana bats?*

A: It really depends on the habitat the bat is in (e.g., heavily forested Tennessee vs. patchwork Indiana), but they tend to stick to forested areas with water. I plan on conducting landscape analysis of stopovers as part of my dissertation work.

Estimating Inter-annual Variability in Project Take for Rare Events

Presenter: Jonathan Plissner, Tetra Tech

[presentation]

Co-Authors: Jonathan Plissner, Thomas Snetsinger, Alicia Oller, Brita Woeck (*Tetra Tech)*, Marie VanZandt (*Auwahi Wind Energy)*

PROBLEM / RESEARCH NEED

Incidental take permits (ITPs) require monitoring to demonstrate that the number of fatalities identified are in compliance with estimated take limits established in an Eagle Conservation Plan or Habitat Conservation Plan (HCP). The duration of an ITP ranges from five to thirty years. If take is likely to be stable, one or two years of monitoring may effectively measure the take rate. However, if inter-annual variation is high or operational measures are implemented that are expected to change the fatality rate, longer or additional periods of monitoring will be required to confidently estimate project take. Understanding the potential sources and effects of annual variability in take estimates is important for identifying authorized take limits and for determining the amount of monitoring required to have confidence in the measurement of project impacts, particularly when dealing with what are likely to be rare events.

Objective

Review the implications of inter-annual variability for ITPs and HCPs, and present a case study approach that uses metrics based on small sample sizes or surrogate measures to estimate the infrequent take of listed species at a wind facility.

APPROACH

Fatality estimation plays several roles with respect to Incidental Take Permits:
1. It is used to predict future take, often out 5-30 years, and to set take limits
2. It can serve as a mitigation or adaptive management trigger
3. It can be used to assess compliance with permit terms and other reporting needs

Inter-annual variation in take can be driven by random natural temporal variation, landscape-scale variables such as temporal trends in population size, or operational changes, such as low wind-speed curtailment (LWSC) or deterrents. It is important to distinguish between random

natural temporal variation and the other two (directional) sources that drive change in the take rate. In analyzing data where the estimated rates of take change over time, it is important to have both a trigger for identifying when a change has occurred and a metric for measuring that change. Triggers and metrics may vary depending on the cause of the change and the data available for estimating the change.

Inter-annual variation raises several considerations for fatality estimation.

- What are appropriate sample sizes, intensity/frequency of monitoring efforts?

- How will variation affect fatality estimates?

- Sources of variability affect how we evaluate the effectiveness of operational changes and deterrents:
    - When does change occur?
    - What is the scale of change?
    - Confounding variation

Rare Events pose particular difficulties for ITPs and conservation plans.

- We can expect that events involving rare species will be rare; they may also have low detectability.

- Certain fatality estimators are not as good at providing precise estimates when the number of fatalities is very low.

- Variability results in larger confidence intervals for rare events. One or two additional fatalities is much more significant than if you were expecting to find one or two fatalities than if you were expecting to find 20.

There are a couple of approaches to dealing with fatality estimation for rare events, including when possible, use of more common surrogates for estimating impacts. The "evidence of absence" model also can be useful in this situation.

Case Study

Auwahi Wind Farm, located in East Maui, comprises eight wind turbines which began operation in December 2012, with an anticipated operational life of 20 years. In February 2012, a habitat conservation permit (HCP) was issued, covering four endangered species potentially associated with the project: Hawaiian petrel, Hawaiian goose, Blackburn's sphinx moth, and Hawaiian hoary bat.

This case study focuses on the hoary bat. There is limited information about this species, and even some dispute about its taxonomy (there may be two distinct species present). Low numbers of acoustic detections and lack of roosting habitat onsite, along with low mortality at nearby wind facilities, led to low take limit for the Hawaiian hoary bat in the original HCP: direct take of 19 adults, and indirect take of 8 young over the 20-year project life.

The long-term monitoring strategy utilizes pulsed standardized monitoring periods: two years of intensive monitoring, followed by periods of systematic monitoring and interim inspections. There were associated carcass persistence and searcher efficiency trials. The evidence of absence model was used for fatality estimation and for identifying whether mitigation triggers had been reached.

Variation in fatalities for the Hawaiian hoary bat may be attributed to both natural and operational sources:
- Natural: random, seasonal, population changes, environmental fluctuations
- Operational: LWSC in February 2015, deterrents, other

The monitoring pulses are timed to provide measures of estimated take over the life of the 25-year permit. Standardized monitoring allows for the identification of temporal changes resulting from landscape-scale changes such as population size, and for the measurement of the effectiveness of implementation of LWSC.

FINDINGS

There is strong evidence that LWSC is effective in reducing take of migratory tree-roosting bats, and we assume that implementation of LWSC is a source of change in the estimated take rate. Therefore, the implementation of LWSC alone serves as the trigger for incorporating a change in estimated take rate into the estimation of project take. The measurement of a perceived change in take is quantified by comparing the median value of annual take from the baseline to the changed condition.

During the first four years of monitoring, we found a total of 12 carcasses. Slide #11 shows estimated rates pre-curtailment (1 bat in 2013, 3 bats in 2014) and after LWSC was implemented: 1 bat in 2015 and 7 in 2016. Sample sizes are too small for us to determine the effects of the curtailment, and it is not clear if 2016 represents an anomaly or not. It seems unlikely that curtailment would result in higher take.

Even pre-curtailment, take was higher than anticipated, which led to the HCP being amended. We developed several different estimates for total (future) take, and recommended the implementation of several additional tiers to cover the range of potential overall take for the project [slide #12] over 20 years.

CONCLUSIONS / APPLICATIONS

The key take-away messages from this work are that:
- Variation in fatality rates affects predictions of take and approaches for assessing compliance with permitted levels of take.
- When take occurs rarely, measuring effects of variation poses additional challenges for monitoring and assessment.

- Planning for alternative outcomes should be considered early in the process, as effects of variation and changes in take may not be discernible, especially with small samples from rare events and few years of monitoring data.

Indeed, we may not be able to measure effects for some species at single projects. Meta-analyses across projects are key to understanding the effectiveness of deterrents in these cases.

Questions & Discussion

Q: *Can you describe the operational adjustments implemented in 2015-2016?*

A: Curtailment was implemented at 5 m/s cut-in speed, and Auwahi currently plans to continue to curtail at lower wind speeds during the period from 30 minutes before sunset to 30 minutes after sunrise.

Q: *Will the HCP adjustment address a different take limit, and in turn what will be additional measures to address the take? Will there be additional mitigation to offset take/impacts?*

A: Yes, there will be an additional take limit requested and associated additional mitigation requirements. Additional minimization and avoidance measures that will be considered include approved modifications to curtailment protocols that may improve effectiveness and potential implementation of deterrent technologies. In addition, the implementation of such measures would trigger additional monitoring.

Q: *How many individual bat carcasses was your estimate based on, and what survey protocol did you use (how often were towers searched)?*

A: Twelve carcasses have been found to date, with the yearly breakdown in the table on Slide #11. During 2013 and 2014, intensive monitoring involved full plots around each of the eight turbines, with seasonal variation in how frequently monitoring took place. Systematic monitoring that began in 2015 was twice a week, and conducted on roads-and-pads of all turbines.

Q: *Could you expand on your comment that there may be two species of hoary bats?*

A: Some genetic evidence suggests that there may have been two or more colonization events for hoary bats in Hawaii, and not sufficient mixing, potentially resulting in two distinct taxa.

Publication? Most of the issues discussed will be in the HCP amendment.

Using Advanced Technologies to Study and Minimize Impacts

Moderator: Chris Farmer, *DNV GL Energy*

Stereo-optic High Definition Imaging:
A Technology to Understand Bird Avoidance of Wind Turbines

Presenter: Evan Adams, Biodiversity Research Institute

[presentation]

Co-Authors: Evan Adams (*Biodiversity Research Institute)*, Steve Burns (*HiDef Aerial Surveying Limited*), Emily Connelly (*Biodiversity Research Institute*), Christopher Dorr (*University of Maine*), Melissa Duron, Andrew Gilbert, M. Wing Goodale (*Biodiversity Research Institute*), Reinhard Moratz (*University of Maine*)

PROBLEM / RESEARCH NEED

Monitoring bird interactions with wind turbines is a challenge in any environment. The direct impact of birds colliding with wind turbines, whether – terrestrial or offshore – can also be considered from the flip side: how birds react to avoid collision. New technologies are needed to document bird behavior around turbines at a variety of spatial scales, particularly those that can identify species of conservation concern, quantify movement patterns accurately, and consistently monitor turbines in a variety of environmental conditions. As bald and golden eagles are significant issues for wind farm permitting in terrestrial environments, we focused our development efforts on these species to improve the opportunities for mitigating collision risk and understanding the mechanism of turbine avoidance.

Objective

Develop instrumentation capable of helping us examine avoidance behavior at the individual turbine scale, and also within turbines and at the wind farm scale. This presentation reports on the results of the efficacy of the system in detecting eagles and other birds around turbines and other study sites.

<u>APPROACH</u>

A collaboration between Biodiversity Research Institute, HiDef Aerial Surveying, Sun Edison, and the University of Maine has been developing a stereo-optic high definition camera system designed to detect animals and then track their movements around wind turbines. Using motion segmentation, this system can automatically detect moving objects and mask aspects of the image that are not moving, allowing focus on objects of interest.

The system [shown in Slide #4] employs two offset wide-angle, ultra-high definition cameras to create a stereo-optic view of the area surrounding the turbine for estimating the position of animals in each frame they are observed. It is compact and self-contained, with low energy requirements and equipment housing suitable for the offshore environment, easily moved and able to send data to a remote computer for post-processing.

To assess the camera system's ability to detect and track eagles in 3-D, the system was deployed at an operational wind farm as well as at sites with high eagle activity in Maine:

- Long-term monitoring at three sites with eagle activity:
  - Terrestrial wind turbine in Maine
  - Coastal estuary in southern Maine
  - Reservoir in southern Maine

- Eagles and other bird species were documented at these sites to determine the:
  - Accuracy of the stereo-optic position estimation
  - Range of detection and identification processes for the system
  - Effectiveness of object identification via shape filtering

Slide #7 shows how the two fish-eye lenses (very wide angled lens) allow us to see most or all of the rotor swept zone, and document how animals are interacting with the turbine. The software ignores stationary parts of the image in subsequent frames, so that only sections of the scene containing moving objects are recorded, resulting in image files that are smaller and require less bandwidth [Slide #8].

Stereo-optic position estimation uses two synchronized cameras to estimate distance of the object when the distance between the cameras is known. Because we are using fisheye lenses, the image must be rectified first and this can create challenges for accurate distance estimation. Distance can also be determined using known averages of wingspan or body length of individuals identified to the species level to determine how far away the animal is using a ratio between number of pixels of the object and the size of the camera sensor. This depends on correct identification of the species that has been detected, but it is a reliable way to validate the stereo-optic calibration for a subset of the data.

We wanted to assess the efficacy of the system using the animals it is meant to track, so employed a technique called distance sampling that often is used on point count surveys with human observers. Within a distance detection framework, the chances of detecting an animal

decreases non-linearly with distance from the observer (see Buckland et al. 2001 for significantly more detail on this process). By using the distance of first detection, we can evaluate how many animals we could have seen with the system but didn't because either:

1) we did not identify them and did not obtain a position estimate; or

2) they were not detected via motion segmentation.

We conducted this analysis in a Bayesian modeling framework using JAGS to set a Markov chain Monte Carlo analysis (Just Another Gibbs Sampler, mcmc-**jags**.sourceforge.net/).

FINDINGS

Eagles were consistently detected by the system, which allowed for position estimation. Further developments to the camera system should provide enhanced capabilities for filtering objects, in turn improving eagle detection. Slide #15 shows the detection curve for eagles, and Slide #16 for other birds ranging from crows to tree swallows. Actual detections are graphed as a percentage of the theoretical limit of detection – that is, if every animal within 400 m (the camera system's assumed limit) were detected. The instrument does quite well out to about 100 m. The camera does good job of detecting objects, but is limited by the extent to which it can "see" the animal well enough to identify it. About 15% of eagles and about 7% of smaller birds were successfully identified out to 400 m with the greatest percentage of the detections occurring within 100 m.

CONCLUSIONS / APPLICATIONS

- Motion segmentation and the data storage reduction features were both found to be effective.

- Position estimation needs improvement. The current methods only work for identified individuals or for animals close to the camera. The camera does work well in offshore environment. Fish-eye lenses allow us to capture wide area with a single installation, but have limitations in terms of how far away from the camera we can detect and identify animals.

- Shape recognition – using size and shape outlines to quickly screen a lot of data and pick out the animals of interest – is in the early stages but shows promise. Additional methods for nocturnal monitoring are currently being explored in a collaboration with Pacific Northwest National Laboratory.

Understanding eagle (and other protected species) movements around wind farms will be important for reducing permitting uncertainty for developers and reducing the adverse effects of wind energy development to birds.

Questions & Discussion

Q: *At what distance from turbines do you need to accurately detect in order to understand a bird's avoidance behaviors?*

A: It depends on the scale of avoidance desired. What we have now would work for micro-avoidance – at the turbine level within a site.

Additional questions not addressed during session Q&A

Q: *What is the confidence level of species identification based on shape patterns?*

A: We don't have firm numbers on this yet but the early results are promising.

Q: *How does motion segmentation deal with motion of non-target objects, such as spinning turbine blades, clouds, wind-blown vegetation, etc.?*

A: It doesn't; you have to use other tricks to find the objects that you are looking for like pattern recognition, masking, or human intervention.

Q: *What number of pixels do you need to reliably detect a bird? Could a similar system be effective for bats?*

A: It varies from species to species mostly by size. In theory it could be used for bats but they are small and you'd have to be using thermal cameras or nIR illumination to track them at night. You would lack a lot of information needed for species-level identification.

Q: *How are you calculating the "theoretical" limit of eagle and non-eagle detections?*

A: We figured that we couldn't determine if an animal was an eagle if it was less than 14 pixels. This number of pixels corresponds to a certain distance to the camera based on the body size of an eagle so I just assumed that we could never ID an eagle from further than that distance.

Q: *Rather than rectifying and then doing a stereo-optic calculation, can you avoid that first step? Would that achieve greater accuracy?*

A: Rectifying the image provides a lot of advantages in calculating position but we could explore this idea.

Q: *Will your cameras eventually have infra-red capabilities to identify bat interactions with turbines?*

A: We have had limited success using nIR illumination but we will be testing this more in the future, and we hope that we will get something to work better.

Q: *What millimeter lens did you use on the cameras?*

A: We used a 15 mm lens.

Comment: Better longer-distance distance estimates could be achieved if your cameras were farther apart.

Response: True, though there are technical issues with spacing the cameras far apart also. We would like to space them further apart if possible. Using different types of lens would help, too.

Heterogeneous Sensor Fusion for Autonomous Detection of Wildlife Collisions with Wind Turbines

Presenter: Roberto Albertani, Oregon State University

[presentation]

Co-Authors: Roberto Albertani, Matthew Johnston, Robert Suryan, Congcong Hu (*Oregon State University*)

PROBLEM / RESEARCH NEED

Mortality of endangered or protected avian and bat species resulting from interactions with onshore and offshore wind turbines is a major conservation concern. We rely on monitoring of wildlife interactions to make and support turbine siting decisions and to validate the effectiveness of siting practices, operational mitigation, and active or passive wildlife deterrent measures. An effective monitoring system would be able to detect bird or bat strikes and identify fatalities to species. Ideally, such monitoring could be conducted efficiently and even be largely automated, capable of working both at terrestrial and offshore wind facilities. Such an autonomous and efficient system currently does not exist.

Objective

Remove market barriers to offshore wind development by designing and field-testing a novel multi-sensor system based on an existing proof-of-concept sensor array capable of automated strike detection and species recognition for use in monitoring fatalities and assessing the effectiveness of deterrents at wind facilities both offshore (where carcasses can't be retrieved) and on land. With appropriate data post processing the system could also perform blade-health monitoring.

APPROACH

We received funding from the Department of Energy to develop a system for off shore wind turbines to detect collision events on blades using sensors that measure vibrations and in turn trigger cameras for event confirmation and species identification. Such technology is needed to

certify the effectiveness of deterrents. To be effective, a system would need to be more efficient than the current methods being used at terrestrial wind facilities, and would need to function in the offshore environment where we currently have no good methods for monitoring strike-related fatalities.

<u>FINDINGS</u>

The existing system consists of an integrated sensor package developed around five fundamental sensor types:

- Accelerometers (vibration nodes) mounted on blades
- Contact microphones mounted on blades
- visual and infrared cameras mounted at the roots of the blades to identify targets
- bioacoustics microphones

A 10 cm box contains the batteries, micro-camera, and the acoustic sensor and accelerometer in a weatherproof case. Vibration, optical, and bioacoustics sensor nodes are controlled by a central computer located in the nacelle. Vibrations are processed to detect impact events in real-time. A ring buffer stores data from before and after the event and transmits that event data, triggering the cameras and microphones.

This system was tested by firing 57-g tennis balls at the blades at a 1.5 MW GE turbine at the North American Wind Research and Training Center at Mesalands Community College in Tucumcari, New Mexico. Additional tests were conducted at the NREL-National Wind Technology Center in Boulder, Colorado. Vibrations from the ball hitting a single turbine blade, was detected not only from the sensor on that blade, but from sensors on the other two rotor blades. This indicates that, while cameras are needed on all three blades to identify the collision target, mounting sensors on all three blades may not be necessary. This and other lessons learned for system design and components inform the development of a new system that also will take advantage of smaller and improved electronics.

<u>Second-generation module</u>

With funding from the Department of Energy for eagle detection and deterrence, we will be able to build and test a new multi-sensor module. The future version of the platform, currently under development, prioritizes board-level integration to significantly decrease the size, weight, and power consumption of the sensor unit. The new research platform, designed for extremely small size, will integrate a 3-axis MEMS accelerometer, 3-axis gyro, low-power CMOS imager, and contact microphone with on-board computation to enable local processing of sensor signals and detection of strikes in real time.

Heterogeneous sensor fusion will allow removal of blade rotation motion artifacts and generator-induced vibrations to lower the overall noise floor. Importantly, localized computation also enables wireless transmission of only detected events in place of continuously streaming raw data, which dramatically reduces power consumption. The

platform will be powered through a battery with possible integration from rotational or vibrational energy harvesting and small solar panels.

This core sensor platform can be adapted for on-blade use or modified for permanent, embedded installation during blade fabrication. The unit will integrate both Bluetooth Low Energy (BLE) and WiFi modules for investigation of appropriate node-node and node-nacelle communication links, and it may include a 3G uplink for cloud-based data logging. The system can also be integrated with appropriate deterrent systems.

CONCLUSIONS / APPLICATIONS

This system for detection of blade strike with images capture for species recognition has two important advantages: system operation is automatic, and the system can be installed on any wind turbine (new or retrofit).

The new **fully blade-mounted**, version of this system will improve sensors' fusion, communication and post processing. With specific post processing the system could be used for monitoring blade health as well as other turbine components. We look forward to reporting on the new system in two years.

Questions & Discussion

Q: *Can your system differentiate between bird impact and ice throw event?*

A: Yes, because vibration triggers camera, and that will allow us to differentiate.

Q: *Is it sensitive enough to pick up 10 gm bat? (Could test with something like a nerf ball with internal framing.)*

A: Right now it is a challenge to pick out something that small out of the background noise. We do not yet have enough data to say. If the impact occurs close to the tip, probably yes; but closer to the nacelle, no. If we want continuous recording, we could look at visual – but we are currently working with daylight cameras, so we would need to add a (fairly low-cost) infrared camera to pick up night-time strikes. Enhanced post processing in the new-generation system should make it possible.

Additional question not addressed during session Q&A

Q: *Is technology available that could be blade mounted to detect collisions of large raptors (using sound, for example)?*

A: The new-generation blade-mounted system will be designed with an open architecture with the capability to accept and control new sensors, like bio-acoustic microphones, or deterrents, like laser or acoustic devices.

Ultraviolet Illumination as a Means of Reducing
Bat Activity at Wind Turbines

Presenter: Paul Cryan, U.S. Geological Survey, Fort Collins Science Center

[presentation]

Co-Authors: Paul Cryan (*U.S. Geological Survey, Fort Collins Science Center*), P. Marcos Gorresen (*University of Hawai'i at Hilo, Hawai'i Cooperative Studies Unit*), Dave Dalton, Sandy Wolf (*Bat Research and Consulting*), Frank Bonaccorso (*U.S. Geological Survey, Pacific Island Ecosystems Research Center*)

PROBLEM / RESEARCH NEED

Tree-roosting bats die often at the blades of wind turbines, but the reasons for this higher susceptibility of "tree bats" remain unknown.

Our understanding is limited by observations made within 50 m or so of the tower (fatality searches, acoustic detectors, thermal video). When we observe bat behavior using thermal cameras pointing up the tower, it looks like close attraction occurs, but it's like watching panoramic events through a keyhole. Our mitigation efforts are likewise limited to this proximate space. If we could see more of what is happening with bats further away (km scale) from the turbines, it might expand our understanding of underlying causes and help us to minimize attraction from afar.

One possibility is that bats might not be able to discriminate wind turbines from trees. Attraction from afar may be a chronic problem of bat fatalities at wind turbines, because distant attraction could act against or beyond the influence of many curtailment and deterrence strategies. "Animals don't think and reason in words" (Temple Grandin) – so what might bats be sensing?

APPROACH

Echo-location is a close-proximity sense: 100-200 m at best, less than 20 m in poor atmospheric conditions. Bats use echo-location to target prey (insects) within 5 m. At greater distances, they rely on vision. Despite low visual acuity, bats are not, in fact, blind – they orient visually when moving across landscapes, and can see the silhouettes of trees from great distances in darkness. Trees being an important resource for bats, this is a plausible distant-attraction cue. Bats are using sensory memories that are ingrained, perhaps, in its DNA – based on ancient old-growth forests. If we want to help bats better distinguish trees from turbines at a distance, we have to imagine what a turbine "looks like" to the bat, and how to make it look less like a tree – that is, a resource.

Integrating the hypothesis of long-distance attraction to turbines that bats mistake for trees with the knowledge that bats see light in the ultraviolet (UV) spectrum, we have pursued the possibility that dim UV light could be used to visually enhance or otherwise alter bats' visual perception of turbines so that bats perceive them differently from long distances, and would thus be less likely to approach them and be killed by turbine blades.

There are several reasons for using very dim (less than ambient light at twilight) ultraviolet light:
- It transmits easily;
- It is visible to bats but outside the human spectral range and sensitivity range of birds;
- It is too dim to attract insects.

FINDINGS

In 2014, we began an ongoing, multi-year effort to assess the practicality of using dim UV light to keep tree bats from turbines.
- Tested & confirmed that seven diverse bat species see dim UV
- Decreased hoary bat activity by flickering UV on trees
- Tested prototype UV light system on an operating turbine

Promising results led to filing a patent application for a "Selectively Perceptible Wind Turbine System" in December 2015. We are moving forward with this research and are planning to conduct a full efficacy trial on operating wind turbines in 2017 if we can obtain sufficient funding and a willing industry partner. The system to be tested would involve UV illuminators mounted on the top and bottom of the turbine nacelle, with bat activity & fatality monitored by tower-mounted thermal cameras. We hope to experimentally UV-illuminate ten turbines for 70 nights at a high-fatality wind facility.

CONCLUSIONS / APPLICATIONS

Now planning a high-fatality site, equip 10 turbines with UV emitters for a few months, use thermal surveillance cameras and fatality monitoring to test this technology experimentally.

If changing the visual appearance of the turbine does reduce close activity and fatality, it is a simple, consistent, relatively low-cost solution. Even if it doesn't work, testing this will help us understand whether bats are in fact attracted to turbines from further away. Knowing more about the cause of attraction will help us find the best minimization strategies.

Questions & Discussion

Q: *Dim UV was initially proposed as a way that cave-dwelling bats find their way out of their roosts or hibernacula, which suggests bats approach dim UV*

A: Experiments have shown that bats confined in a small space, such as a box or other enclosure, will use light as a guide for finding their way out. We call this the "escape-toward-the-light response" because it is a very specific behavior probably unique to emergency situations. Light is a quick and easy cue that trapped animals can use to identify an escape route. However, this was just a behavior we manipulated to confirm experimentally that bats can perceive extremely dim UV light that we humans could not. We expect the opposite effect with bats flying in the open, which we know are not directly attracted to sources of light or lit surfaces (although a small proportion of bat species can be indirectly attracted to lights in certain situations if making use of insect aggregations).

Q: *Could the UV emitters interfere with other technology or sensors, for example airplanes?*

A: Our dim UV lights would not interfere with any technologies that we know of at this point. A key benefit of our approach is that we are working at wavelengths and intensities of light that are outside of and below, respectively, the visual range of humans and most if not all birds. The intensities of light we use are generally lower than ambient light levels at dusk and another major advantage is that our focus is on lighting turbine surfaces rather than shining lights directly out into the airspace around turbines and toward flying animals. Lights for an entire turbine run from a single cord plugged into a 120V standard electrical socket inside the turbine nacelle and are unlikely to produce electrical interference with other turbine instruments. Not only are these low-intensity lights hard to see from the ground when looking directly into the light source, but another goal we are aiming for is to try illuminating turbine structures sufficiently without pointing UV lights outward. We may end up concealing them completely, such as pointing lights down from inside the nacelle-monopole junction to illuminate the upper half of the monopole on all sides.

Q: *How might you account for inter-annual variation in fatality rates when testing this new technology?*

A: Variation in bat activity and fatality over time is a huge challenge when testing any new deterrent technology on wind turbines. Our research group developed the use of thermal surveillance video cameras to quantify bat activity and fatality risk at turbines over very long periods of time (continuous nightly monitoring for 3-9 month periods), which gives us more information to work with than data from acoustic detectors or fatality searches alone, so that helps. Although we cannot identify the species and genera of bats observed with thermal surveillance cameras, we can see whether bats are interacting with the turbines when present in the nearby airspace and how often they have close calls or contact with moving blades.

After a lot of video observations at different kinds of wind facilities, we have a pretty good understanding of how activity and fatality can vary widely from night to night and among seasons, and how bat visits to turbines can often be rare events. These observations help us get a handle on the statistical power needed to detect an effect of a deterrent. Variation in bat fatality rates between years will indeed be a big challenge to testing any deterrent technology, but variation <u>within</u> years is a more immediate problem. We have calculated that to first overcome this variation within years, the deterrent technology needs to be tested at a facility

experiencing high rates of bat fatality (e.g., > 50 bats/turbine/year) and during periods of peak fatality (e.g., July-October).

Even with the enhanced amount of data available through video surveillance during the peak fatality season, studying deterrent effects at sites with lower rates of bat fatality would require equipping more turbines with deterrence devices and monitoring for longer periods of time. In short, working at high-fatality sites lets us gather enough relevant observations to overcome variation, or noise, in the analysis. If we carry out a well-designed study that overcomes within-year variation to show a positive effect of our UV deterrent, the next step would be to expand testing at more facilities over multiple years and seasons to see how the effects might change among seasons and years.

Q: *Many birds can see in the UV spectrum (350-390 nm), which overlaps the wavelength you used. How might the UV light on turbines affect birds? Likely to attract or to deter? Also, might the UV light attract insects, which in turn would attract bats?*

A: Yes, many species of birds can see very well in the UV spectrum at brighter light intensities. The vision of birds is far superior to bats in terms of seeing fine details of shape and color in bright light (higher visual acuity). However, key concepts underlying our dim UV approach are that, in general, many mammals have more sensitive vision than most birds, and that bats have some of the most sensitive vision of all mammals. Bat vision is extremely sensitive and bats can see in low-light conditions that humans and even owls would perceive as darkness. A few kinds of birds (e.g., nighthawks and oil birds) have visual sensitivity approaching that of bats, but there is no evidence that those birds have that kind of high sensitivity in the UV spectrum like bats. Birds that see UV light probably rely on cone cells in their eyes, which are only triggered by brighter light and may only be functional in daylight. UV vision in bats is very different and is likely attributable at least in part to the much more-sensitive rod cells in their eyes.

We carefully designed our UV method to be imperceptible to birds, so we do not expect their attraction, deterrence, or possible harm (e.g., causing temporary night blindness). We have been very careful to design a 'passive' deterrence system that does not inadvertently affect animals flying past the turbine at night that would otherwise not interact with or be influenced by its operation. Our approach follows the veterinary/medical precept of "First, do no harm."

We have deployed prototype UV illuminators under field conditions for many nights, including ten nights on an operating wind turbine, and have seen very little evidence that large numbers of insects concentrate in the airspace around the UV lights. Experimental studies elsewhere showed that UV lights of brighter intensities than those we use only attracted moths from within about 100 meters, and there is evidence that although the eyes of insects can physiologically detect pure UV light at extremely low intensities, it may not be the UV components of the spectrum that attract them to lights at night. Few studies have examined whether insects are attracted at night to pure UV light (as we create with our illuminators), most insect attraction studies used light sources that included components outside the UV spectrum (>390nm) or did not account for visible fluorescence of nearby objects, and new studies show clear attraction of insects to bright sources of illumination that do not have UV components (e.g., LED lights). In our experience thus far, our UV lights do not attract enough

insects to attract bats, and the jury may still be out on whether UV components of the spectrum are what actually attract insects to lights at night.

Q: *Will you also monitor the test turbines acoustically? Video detects only a small fraction of the bats that are present.*

A: We will deploy acoustic detectors on a subset of turbines during experiments for methods comparison data, but will rely on thermal video surveillance as our primary and most reliable measure of bat activity and fatality. Although acoustic detectors can be a cost- and labor-saving technique for monitoring bat activity at turbines, we have reason to question the usefulness of acoustic detectors for characterizing and quantifying meaningful bat interactions with wind turbines.

Our experience tells us the opposite is true of the statement that "Video detects only a small fraction of the bats that are present." During three months of observations at a wind facility in Indiana using ground-based, low-resolution thermal surveillance cameras and two types of acoustic detectors mounted on the top and back of the turbine nacelles, our research revealed that more than half of the bats detected acoustically above the nacelle were not observed on video from the ground, probably because the detection zone of those thermal cameras reached just a bit higher than the turbine nacelle.

In that same study, we did not detect bats acoustically during 42% of the events in which we detected them on video flying near turbine blades, monopoles, and nacelles. This disparity likely resulted from bat detectors mostly monitoring the airspace above the nacelle and picking up bats flying in the upper rotor-swept zone and above, while video cameras monitored activity mostly from the nacelle downward and bats flying in the rotor-swept zone. It was unclear during that study whether the lack of acoustic detections associated with video detections was due to placement of bat detectors on top of the nacelles, but we observed many instances on video where bats flew within a few meters of acoustic detectors that were thought to be functioning, yet calls were not recorded.

In a subsequent six-month study using higher-resolution thermal cameras and acoustic detectors with microphones pointing backward and downward from the turbine nacelles, we observed several thousand events involving Hawaiian hoary bats on video, yet only acoustically detected bats at those same turbines several hundred times during the study. Our observations lead us to believe that bats sometimes/often forgo echolocation when approaching wind turbines (and perhaps other structures like roosts), that acoustic detection of bats from turbine nacelles is more difficult than currently appreciated, or some combination of these possibilities. Either way, we believe that video monitoring is the best way to measure bat activity near turbine towers, as it serves as a reasonable metric of bat presence in places where they are at greatest risk of being struck by moving blades.

Q: *Do we know anything about bats' ability to learn to distinguish turbines from trees?*

A: No, not yet. Our video observations from turbines in Indiana and Colorado suggest that migrating bats approach turbines closely for very brief periods before moving on. Our video observations from Hawaii suggest that resident bats foraging near turbines seem to pay less

attention to them and closely approach turbines less often than migrating bats. Our UV approach is based on the idea that bats figure out turbines are not trees soon after they closely approach them, but that we can help them make that determination from farther away so they do not need to approach so closely.

Q: *Could the UV illumination approach be effective for non-tree bat species?*

A: Possibly. We tend to bin bats into categories like 'tree bats' and 'cave bats' for conceptual convenience, but these categories are arbitrary. For example, species of bats that roost in caves during winter, like Indiana bats and northern long-eared bats, move into trees during the warmer months, and so could technically be considered tree bats. Even for species that we currently do not know regularly roost in trees, such as Brazilian free-tailed bats, they might still key in on trees for various reasons when out and about at night. We suspect that bats are visually attracted to wind turbines because they mistake them for the silhouettes of trees and expect to find some resource at trees during that time of year.

One hypothesized resource they may be seeking is resting places. Any bat that roosts in trees during some part of the year might potentially take advantage of tree roosts, particularly while migrating and moving through areas where its preferred roost structures are less common and harder to locate (e.g., caves). Another hypothesized resource many types of bats might expect could be insects, which accumulate in natural settings on the leeward sides of trees, particularly in late summer and fall (see Cryan et al. 2014, PNAS 111:15126-15131). Any species of bat that eats insects might have evolved to exploit such seasonal and landmark-based banquets, regardless of the way the species roosts during the day and how we humans categorize them. If our UV approach works, we hope it will work for more than just 'tree bats'.

Q: *Did you experiment with different levels and durations of UV light flickering? If so, were certain durations more effective than others?*

A: We have not yet had the opportunity to experiment with different light intensities and durations on turbines. Our long-term goal is to reduce fatalities with the lowest-intensity illumination possible, but lower intensity light might take slower flickering (that is, longer 'exposure' time) to be perceptible to bats. For efficacy testing we are using light that is below the intensities that can be seen by humans and birds, but still fairly high on the scale of what bats can likely see. If we get a favorable response at this initial intensity and flicker rate, we will experiment with lower and more efficient combinations of intensity and duration.

Q: *Has the idea of adding UV to existing FAA lights been considered?*

A: FAA lights are designed to cast high intensity red and near-infrared light out into the airspace around the turbine, only illuminate small areas of the turbine surface, and be visible from very far away. It would not be practical to implement our UV approach through integration with FAA lights because we are trying to illuminate the turbine surfaces with light the bats are more likely to see and at much lower intensities. The visual capabilities of bats drop off near the red end of the spectrum and it is not clear whether bats can actually see ultra-low intensity red light. Prior studies and our own experiments confirm that the eyes of most bat species are most sensitive

to light in the UV, blue, and green parts of the color spectrum. Furthermore, casting UV light from FAA lights at the same intensity used for aviation warning has the potential to attract insects from greater distances and be visible to humans or birds, as well as reach intensities more likely to cause visible fluorescence of turbine surfaces.

Disclaimer: This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Reduction of Eagle Take at Windfarms through Machine Vision Enhanced Informed Curtailment

Presenter: Tom Hiester, *Renewable Energy Systems*

[presentation]

Co-Authors: Tom Hiester (Renewable Energy Systems), Tim Hayes (Duke Energy Renewables), Greg Aldrich (Duke Energy)

PROBLEM / RESEARCH NEED

Informed curtailment is a method whereby individual or groups of wind turbines in a project are shut down when an eagle is at risk of a collision with rotating wind turbine blades. The decision to curtail is based upon data gathered by human observers. Human observation techniques have strengths and weaknesses. Our hypothesis is machine vision solutions overcome some of these disadvantages thereby creating a stronger informed curtailment program than is achievable by human observers ("bio-monitors") alone. These capabilities may enable species specific automated curtailment capability that minimizes take risk and maximizes wind turbine operating revenues subject to wildlife protection constraints.

Objectives
In this paper, a comparison of human bio-monitor observation of eagle activity and resulting curtailment decisions are directly compared with machine vision observations and a variety of curtailment recommendations based on varying curtailment prescriptions.

APPROACH

Duke Energy's Top of the World wind farm near Caspar, Wyoming has made it possible to test the premise that "machine vision" could be useful in making curtailment decisions and provide a platform to compare the potential effectiveness of machine vision to bio-monitors.

- ***Bio-monitor-based informed curtailment*** – There are three bio-monitor observation points located within the 18,000-acre wind farm. A human observer in a tower can shut-down a turbine within seconds if an eagle is spotted.

- ***Machine vision-based curtailment*** – Four IdentiFlight® towers [see slide #4], each with eight fixed-position wide-angled cameras, can detect eagle-sized objects out to approximately 1000 m. The fixed cameras also are able to distinguish relevant from irrelevant motion. Detection and preliminary identification of an eagle triggers use of a high-resolution stereoscopic camera that can move and measure distance to 4% accuracy. The high-resolution cameras can measure wingspan and wing profile shape, collect other data for machine vision species analysis, and track the bird.

When an image meets both identification as an eagle and distance criteria (within 400 m of turbines), it can send signal to the SCADA to curtail turbines.

FINDINGS

Proof of Performance testing was conducted in the field for four weeks through the AWWI Tech Verification Program, with subcontracts to Peregrine Fund and Western EcoSystems Technologies, from August to early September 2016. Testing objectives included:

- Detection reliability

- Classification accuracy – Eagle or Not-eagle

- Time from detection to identification

- Distance from turbine at which classification occurs

Point counts were conducted at each of the four IdentiFlight® towers for four observation periods of one hour-and-45-minutes, with observers rotating to a different tower site each day. Observers noted data and marked flight paths on a map [Slide #9]. These observations were compared with coincident data from the IdentiFlight® systems. Slide #11 shows two views of all the eagle flight tracks registered by one of the IdentiFlight® towers. The "plan" view can be compared with the flight paths marked by human observers. Google Earth provides an elevation view of the same paths, allowing us to see that much of the eagle activity picked up by the IdentiFlight® system took place well above turbine heights, and above the zone that could have been observed using the point count method.

The test showed that while the fixed cameras on a single IdentiFlight® are "blind" to the area directly above it, as a network, cameras from one tower can cover these blind spots above other towers. However, even with this coverage, it appears that eagle tracks above the IdentiFlight® towers are relatively thin; if this is not due to visual occlusion, it may be suggestive of eagle behavior – either they are not frequenting these locations or are actively avoiding these locations.

The table on Slide #13 summarizes curtailment practice at this facility from mid-August to the beginning of October, based on bio-monitor observations of eagle flight under 200 m AGL

within 400 m of turbines, using operator judgment on eagle behavior. A total of 369 Golden eagles and 166 Bald eagles were observed over the 49-day period, and all 110 Top of the World turbines were curtailed on 25 occasions, with the duration of curtailment event ranging from 3 to 20 minutes. Operations were curtailed for a total of 135 minutes (5.4 minutes per curtailment event), resulting in approximately $74 lost revenue to the facility. No eagle fatalities were recorded. These data suggest that not many eagles are exposed and that bio-monitors are very skilled at determining risk level (or very lucky during this period) – or that wind turbines are not very risky to eagles.

Machine-based curtailment requires an algorithm for establishing a set length of curtailment when an eagle enters a pre-determined cylinder space surrounding the turbine. The graph on Slide #15 shows hypothetical lost revenues from curtailment based on proximity to a turbine and mandatory shutdowns of arbitrary length. These data suggest that such simple curtailment criteria are too costly.

A viable curtailment prescription must push machine vision capability further, to distinguish risky from non-risky eagle behavior in the vicinity of turbines.

CONCLUSIONS / APPLICATIONS

It is clear that the machines can see more than people (bio-monitors, point count biologists), and that machine vision is becoming a viable tool for:

- Researching eagle behavior and windfarm interactions
- Raptor pre-construction surveys
- Providing a visual aide to biomonitor-based informed curtailment
- Automatic curtailment

The trade-off between false positive and false negative classification rates could lead to excessive curtailment in high raptor use areas. There is a need to improve our understanding of eagle behavior and develop algorithms to "train" automated systems to distinguish as biologist observers can risky vs. non-risky eagle behavior for machine vision to become an even more cost effective tool. We hope that the image data we are collecting will help us understand how to predict when eagles are likely to be at risk because they are hunting, for example, versus when they are just flying through with their heads up. The analysis of these images should be completed December 2016.

Questions & Discussion

Q: *Once IdentiFlight® identifies a bird as an eagle, is it able to correct a misidentification?*

A: Yes. We of course are striving to never have misidentified a non-eagle bird as an eagle (False Positive); we can set the tolerances for this to be more conservative or more aggressive to control the amount of False Positives. Our performance testing through the AWWI Tech

Verification Program should determine our False Positive and False Negative rates. Each frame, and we collect 3 to 5 frames per second, does measurements and analysis, so in part we need to remember the data over the history of frames and make corrections when warranted but not spuriously.

Q: ***How applicable are data and conclusions from Top of the World farm going to other wind project sites with eagle concerns?***

A: Species classification should be transferrable. It is helpful to collect training data from other backgrounds, e.g. deciduous trees vs. shrub-steppe. That is likely to be more site-specific. These backgrounds are below the horizon between sky and ground and apply to the lower flying birds. Our sky data is transferable and not site specific.

Additional questions not addressed during session Q&A

Q: ***What size (mm) lens are you using on the stereoscopic cameras?***

A: For our beta units now in the field, we use an off-the-shelf 300 mm variable focus zoom lenses.

Q: ***Approximately how much do those cameras cost?***

A: Production cost in volume is still being worked out. In a U.S. windfarm setting with fairly dense camera coverage, we expect installed cost works out to be perhaps $40,000 - $60,000 per turbine, sometimes more, sometimes less depending on site specific characteristics and order quantity.

Q: ***When a biologist clicks the button to curtail a wind turbine, what is the lag time to when the turbine is no longer moving?***

A: I believe the experience at Top of the World suggests the turbine will begin reacting to the signal to curtail almost immediately. The bio-monitors believe the bird may react to the first few seconds of blade feathering, and I hope to be able to prove this with IdentiFlight®. The rotor will be at a very low rpm within 10 to 15 seconds of the curtailment signal.

Questions for All Advanced Technologies Panelists

Q: ***As you've tried to develop approaches, what obstacles have you encountered?***

Evan Adams: There are obstacles to knowledge, and to opportunity. Offshore, we lack turbines to field test – although that is starting to change (Rhode Island). I would say that we need more information about what kinds of interactions with turbines matter most for animals (this is from the biological side) and then that should feed into the protocols that regulators require for monitoring.

Roberto: Working with sensors, started with off-the-shelf, had to make it work in outdoor environment. A second thing was vibration nodes and how to deal with background noise when low-energy impact – a challenge to filter out the impact from background. Also challenges to working on top of a turbine tower.

Paul: We've been lucky to find industry partners willing to work with us, but that's a tall order. I drafted a want ad to help illustrate the challenges. "Wanted: Wind energy company able to forgo curtailment at a high-fatality site and give federal scientists access to operate experimental devices on your equipment for a few months without theft or vandalism, and then publicly disclose their observations, regardless of outcome." *Note: this sample want ad was intended to be somewhat facetious and exaggerated to make a point. Our planned test of the UV approach would not necessarily require forgoing curtailment or publicly disclosing observations without appropriate intellectual-property agreements in place.*

Tom: Independent testing is a barrier. We are in the business to make money, so want to sell the equipment we develop, but customers want proof that it works. Field testing is expensive and time consuming, so it is very helpful to have cooperation from prospective customers to test the systems. Risk sharing beyond just the technology provider helps support the technology development investment. Regulatory stability is another barrier. This is capital equipment, so it is an upfront cost--if a customer thinks the rules will change, say bald eagles are no longer a concern requiring minimization, the market uncertainty that results may make people reluctant to invest.

Q: *Given these obstacles, what can we in industry do to help facilitate getting some of these technologies to commercialization?*

Evan: We need clear rules, monitoring protocols, regulators who are willing to be flexible. Industry needs to be flexible too. We need more information about what kinds of interactions with turbines matter most for animals (this is from the biological side) and then that should feed into the protocols that regulators require for monitoring.

Roberto: OSU developed a prototype, but we need companies to collaborate and invest to make something commercial. We have not yet had access to commercial turbines, so will need help from manufacturers; ideally the sensors (though not the cameras) could be mounted inside the blades.

Paul: Easy for me to say from policy-neutral science agency, but we may be most productive if we view bat fatalities at wind turbines as a shared problem that science can solve, rather than a polarizing issue.

Tom: We need innovators from all sectors, including industry. We are in the stage where early adopters are crucial to the initial deployments. To bring along more reluctant technology adopters, we need to make sure that industry members are communicating results among

themselves. Also, I have a feeling that we are going to have an incredible amount of data that will be useful to scientists – come and get it!

Evan: Think about data-sharing across the industry.

Q: *Can you estimate future cost of commercial deployment of this type of system?*

Roberto: The electronic sensors and cameras are pretty cheap: a few hundred dollars of hardware per unit (per blade). Plus computer and wireless connection. Maybe $1K to $1.5 K per turbine. Lower cost than human time.

Paul: In prototype mode the UV lights (360 degree arc, mounted on top and bottom of nacelle pointing forward to dimly illuminate the leeward [back] sides of the tower and outer halves of the blades) cost about $6,000 per turbine. We are not sure if that is the optimal configuration and the way we light turbine structures may change, but cost should come down quite a bit if it works and once we are ready to deploy commercially.

Tom: total investment in developing the IdentiFlight® technology to a point of full commercialization is in the range of several millions to the low $10 millions. Individual system deployment costs depend on a lot of site specific factors, including quantities, location, number of turbines covered, access to power and communications and so must be worked out project by project.

Evan: depends on price of cameras and optics, and stainless steel. A lot more work to do to commercialize.

Research Priorities &
Key Meeting Takeaways

Moderated by Taber Allison and Abby Arnold, American Wind Wildlife Institute

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Research Priorities Discussion

During the keynote address, Taber Allison and Abby Arnold discussed development of a wind-wildlife research plan to define AWWI's priorities over the next five years. The audience was polled live during the discussion to provide a "snapshot" of participant perspectives regarding which species, which impacts, and which research topics they felt were most important.

The American Wind Wildlife Institute (AWWI) staff are developing a wind-wildlife research plan that will define our priorities over the next 5-10 years, and we are seeking broad stakeholder input. The plan will be made public in 2017, but is intended to guide AWWI's priorities. We begin with these premises:

- We've learned a lot, but substantial uncertainty remains.
- Wind energy development will continue, because there is broad agreement about the need to reduce CO_2 emissions. We are working from current national production of 82 GW towards a goal of 330-440 GW contribution to U.S. energy needs in 2050.
- The likelihood of reduced federal funding for research makes it all the more important to set priorities.
- Wind must be able to comply, effectively and efficiently, with wildlife laws/regulations.
- The situation is urgent; we have a lot to learn in a short period of time.

Mobile Group Poll

In the interest of "getting a sense of the room," AWWI conducted a live mobile poll, asking participants (who identified themselves as consultants and state and federal agency employees) for their perspectives:

Species of concern: migratory tree-roosting bats; raptors; sage grouse species

Impacts of concern: collision mortality; displacement from suitable habitat; demographic effects

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Priorities for research: improve impact minimization strategies and technologies; improve risk assessment and siting; evaluate cumulative effects

Most people agreed or strongly agreed that wind energy should receive mitigation credits for offsetting or reducing carbon emissions.

Risk is a function of the probability and the consequences of an event's occurrence. Improving the assessment of risk means decreasing uncertainty associated with both occurrence and consequences. We will never eliminate uncertainty, but we still need to make decisions; there is a lot depending on our ability to reduce reliance on fossil fuels. How much uncertainty are we willing to accept? (Sometimes as we reduce some uncertainty, we uncover other questions.) We need to recognize that some uncertainties are more critical than others – and focus our research on reducing those uncertainties.

Key Takeaways from the Research Meeting

Facilitated by Abby Arnold, American Wind Wildlife Institute

Participants discussed one or more of four "takeaway" questions, then shared in plenary.

What is the most promising or exciting research that you've heard about this week that is leading to solutions?

- Efforts to understand how bats perceive the world and environmental variable that affect how bats behave – we would like to see similar work for eagles.

- Efforts to increase efficiency of current techniques, whether fatality monitoring or estimation, "smart" curtailment strategies and collision monitoring, etc.

- The Nature Conservancy's work to look at areas of low risk for siting.

- Moving away from siting/avoidance focus to siting and adaptively managing risk on the ground

What do we need to increase the rate at which research is integrated into policy and decision making?

Greater Flexibility

- Increased flexibility amongst regulators to allow and support technology that may result in take but needs to be tested.

- We need an adaptive peer-review process. Publication in peer-reviewed journal just takes too long. Need to get feedback from regulatory agencies and industry more regularly as research is being shaped and conducted.

- Where take *is* authorized (e.g., Top of the World project), we need more funding to really do the cool science that will give us all answers.

- Different regulatory pathways for low-risk projects.

- Pre-construction info not well linked to post-construction risk – we need to get away from siting focus and focus on minimizing impacts when project is sited.

Shared Data

- Research is disconnected, and needs to be got into hands of policy and decision-makers, need to synthesize in a way that is useful and meaningful.

- Disseminating information – condensed version of what we learned and getting it out to other FWS staff who are not here. PDF, short presentation – key notes – bullet points.

- Development of a data clearinghouse, with regular updates to let people in industry and wildlife agencies know what data are available.

- Meta-analysis would be valuable. Data needs to be published so we can use it.

Communication and collaboration

- Do a better job of communicating our work (science-driven) to the public, so that there is community support for political decision-making. Multi-tiered community level effort.

- Evaluation of existing technologies, made public so that regulators and permitting agencies can act on it.

- A lot of time devoted at conference to cutting edge, but there is also a need for disseminating more info about "good enough" practice – especially for developing countries. Global biodiversity loss is happening in the tropics and developing countries.

- This kind of multi-stakeholder dialog and collaboration is not as common outside the U.S. Suggest having a list-serve to help people find partners globally, to pursue collaboration more effectively.

What are the top questions or gaps in wind wildlife research?

- We need to identify what has *not* been working so that we can drop less fruitful lines of inquiry and focus our resources on more promising ideas.

- We need to develop and validate eagle deterrents.

- We need to understand the basic biology of migratory bats, and to learn more about offshore bat movement and populations.

- Pre-construction info not well linked to post-construction risk – almost all of the talks focused on post-construction monitoring, but a lot of time and money still being spent on pre-construction studies. As regulators we have to base permitting decisions on those studies, because we don't have anything else to go on.

- Population-level impacts, habitat restoration as compensatory mitigation, being able to quantify and defend that.

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
- Presentations (pdf)
- Posters (pdf)

To learn more about NWCC, please visit: www.nationalwind.org.

To learn more about AWWI, please visit: www.awwi.org.