13th

Wind Wildlife Research Meeting

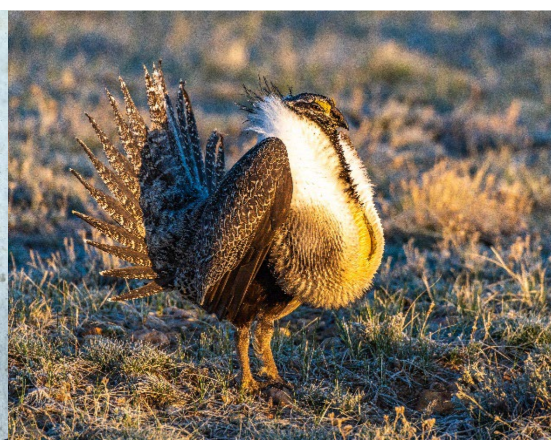
December 1–4, 2020

PRESENTED BY AWWI

Meeting Proceedings

Published May 2021

Prepared by Susan Savitt Schwartz


American Wind Wildlife Institute
1990 K Street NW, Suite 620
Washington, DC 20006
awwi.org

Acknowledgments

The meeting and agenda for the 13th Wind Wildlife Research Meeting were planned by the American Wind Wildlife Institute (AWWI). Production of the Proceedings was co-funded by AWWI and the National Renewable Energy Laboratory for the U.S. Department of Energy.

AWWI wishes to acknowledge and thank the following companies, organizations, and individuals for their support for the meeting:

Platinum Sponsors: DNV • National Renewable Energy Laboratory • Western EcoSystems Technology (WEST), Inc.

Gold Sponsors: Bureau Waardenburg • Clearway Energy Group

Silver Sponsors: Atwell, LLC • Burns & McDonnell • NextEra Energy Resources • Olsson

Bronze Sponsors: Blanton & Associates • Copperhead Environmental Consulting, Inc.
Energy Renewal Partners • Locke Lord LLP • Nossaman LLP • Natural Resource Solutions, Inc. • Tetra Tech

Members of the **Planning Committee**, who contributed extensive volunteer hours in planning this meeting, as well as all others who provided input:

Amanda Hale, Texas Christian University • Amy Parsons, Avangrid Renewables • Brad Romano, Invenergy • Christi Calabrese, EDP Renewables • Cris Hein, National Renewable Energy Laboratory • Dale Strickland, Western EcoSystems Technology, Inc. • Danna Small, Pattern Energy Group • Dave Nelson, University of Maryland Center for Environmental Science • Dave Phillips, Equinor • David Tidhar, Natural Power • Doug Johnson, U.S. Geological Survey • Garry George, National Audubon Society • Hein Prinsen, Bureau Waardenburg • Janine Crane, NextEra Energy • Jay Diffendorfer, U.S. Geological Survey • Jenni Dean, Enel Green Power • Jocelyn Brown-Saracino, U.S. Department of Energy • Joy Page, Defenders of Wildlife • Kate Williams, Biodiversity Research Institute • Katie Umekubo, Natural Resources Defense Council • Kelley Myers, U.S. Fish and Wildlife Service • Kim Wells, NextEra Energy • Leslie New, Washington State University, Vancouver • Manuela Huso, U.S. Geological Survey • Melissa Marinovich, Nebraska Game and Parks Commission • Mike Speerschneider, Formerly American Wind Energy Association • Mona Khalil, U.S. Geological Survey • Pat Deibart, U.S. Fish and Wildlife Service • Phil Whitfield, Natural Research Ltd • Rene Braud, Pattern Energy Group • Sarah Reif, Oregon Department of Fish and Wildlife • Terry Root, Stanford • Todd Katzner, U.S. Geological Survey • Tracey Librandi Mumma, Pennsylvania Game Commission

Those who volunteered their time to **review submitted abstracts**.

The **meeting presenters and speakers** who contributed their work and expertise to the meeting program.

About AWWI & NWCC

The American Wind Wildlife Institute (AWWI) is an independent nonprofit 501(c)3 organization that advances scientific research and collaboration to better understand wind energy's risks to wildlife and develop solutions. Built on a strong partnership of leaders, AWWI works collaboratively with the wind industry, conservation and science organizations, and wildlife management agencies to facilitate timely and responsible development of wind energy while protecting wildlife and wildlife habitat.

Launched in 1993 and formalized in 1994, the National Wind Coordinating Collaborative (NWCC) was initiated and has been supported by the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) to provide an independent forum for a wide range of stakeholders – including government agencies, industry, conservationists, academics, and the general public – to pursue the shared objective of developing environmentally, economically, and politically sustainable commercial markets for wind power in the United States. The NWCC retired in early 2021; learn more at https://awwi.org/nwcc-timeline/.

AWWI plans to continue hosting biennial Wind Wildlife Research Meetings.

Abstract

Wind energy is recognized as a key component of reducing greenhouse gas emissions from energy production. By generating electricity with lower carbon emissions and water use than fossil fuels, wind energy benefits birds, bats, and many other animal and plant species. Yet wind energy development and operation, like most human activities including other forms of energy generation, can pose risks to wildlife. These proceedings document current research pertaining to wind energy-related wildlife fatalities; habitat and behavioral impacts at the project level as well as cumulative and landscape-scale impacts; and avoidance, minimization, and mitigation strategies and technologies. As the window of opportunity to prevent the most catastrophic consequences of climate change narrows, these proceedings reflect discussions among stakeholders – scientists, wildlife agencies, wind energy developers, and conservation organizations – about how to balance the need to understand and mitigate wind energy impacts with the need to expedite responsible development of wind energy.

Suggested Citation Format

This volume:

PNWWRM XIII. 2021. Proceedings of the 13th Wind-Wildlife Research Meeting. December 2-4, 2020. Prepared by the American Wind Wildlife Institute, Washington, DC, Susan Savitt Schwartz, ed. 106 pp.

Preceding volumes:

PNWWRM XII. 2019. Proceedings of the Wind-Wildlife Research Meeting XII. St. Paul, MN November 28-30, 2018. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by the American Wind Wildlife Institute, Washington, DC, Susan Savitt Schwartz, ed. 148 pp.

PNWWRM XI. 2017. Proceedings of the Wind-Wildlife Research Meeting XI. Broomfield, CO November 30 - December 2, 2016. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by the American Wind Wildlife Institute, Washington, DC, Susan Savitt Schwartz, ed. 168 pp.

PNWWRM X. 2015. Proceedings of the Wind-Wildlife Research Meeting X. Broomfield, CO December 2-5, 2014. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by the American Wind Wildlife Institute, Washington, DC, Susan Savitt Schwartz, ed. 139 pp.

PNWWRM IX. 2013. Proceedings of the Wind-Wildlife Research Meeting IX. Broomfield, CO November 28-30, 2012. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by the American Wind Wildlife Institute, Washington, DC, Susan Savitt Schwartz, ed. 151 pp.

PNWWRM VIII. 2011. Proceedings of the Wind-Wildlife Research Meeting VIII. Lakewood, CO October 19-21, 2010. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 191 pp.

PNWWRM VII. 2009. Proceedings of the Wind-Wildlife Research Meeting VII. Milwaukee, WI October 28-29, 2008. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 116 pp.

PNWWRPM VI. 2007. Proceedings of the NWCC Wildlife Workgroup Research Planning Meeting VI. San Antonio, TX November 14-15, 2006. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 138 pp.

POWIWD-V. 2005. Proceedings of the Onshore Wildlife Interactions with Wind Developments: Research Meeting V. Lansdowne, VA November 3-4, 2004. Prepared for the Wildlife Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 120 pp.

PNAWPPM-IV. 2001. Proceedings of the National Avian-Wind Power Planning Meeting IV, Carmel, CA, May 16-17, 2000. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed., 179 pp.

PNAWPPM-III. 2000. Proceedings of the National Avian-Wind Power Planning Meeting III, San Diego, CA, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by LGL, Ltd., King City, Ont., 202 pp.

PNAWPPM-II. 1996. Proceedings of the National Avian-Wind Power Planning Meeting II, Palm Springs, CA, September 1995. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, and LGL, Ltd., King City, Ont., 152 pp.

PNAWPPM. 1995. Proceedings of the National Avian-Wind Power Planning Meeting IV, Denver, CO, July 1994. Repot DE95-004090. RESOLVE, Inc., Washington, DC, and LGL, Ltd., King City, Ont., 145 pp.

Ordering Information

These Proceedings are available in PDF format with accompanying presentations available via links. Proceedings may be downloaded from the AWWI website: awwi.org.

Disclaimer

Some of the presentations described in the Proceedings of the 13th Wind Wildlife Research Meeting may have been peer-reviewed independent of this meeting, but results should be considered preliminary. This document may be cited, although communication with the author before doing so is highly recommended to ensure that the information cited is current.

These proceedings do not necessarily reflect the views of the American Wind Wildlife Institute or those noted above. AWWI expressly disclaims any warranties or guarantees, expressed or implied, and shall not be liable for damages of any kind in connection with the material, information, techniques, or procedures set forth in this publication.

Table of Contents

Abbreviations

American Wind Energy Association (AWEA) – *now the American Clean Power Association*
American Wind Wildlife Institute (AWWI)
American Wind Wildlife Information Center (AWWIC)
Annual energy production (AEP)
Association of Fish and Wildlife Agencies (AFWA)
Avian-Impact Offset Method (AIOM)
Bureau of Ocean Energy Management (BOEM)
Collision risk model (CRM)
Eagle Conservation Plan (ECP) and ECP Guidance (ECPG)
Electric and magnetic fields (EMFs)
Endangered Species Act (ESA)
Generalized Estimator of Mortality (GenEst)
Gigawatt (GW)
Geographic information system (GIS)
Global navigation satellite system (GNSS)
Global positioning system (GPS)
Global system for mobile communications (GSM)
Incidental take permit (ITP)
International Energy Agency (IEA)
Levelized cost of energy (LCOE)
Megawatt (MW)
National Environmental Protection Act (NEPA)
National Renewable Energy Laboratory (NREL)
National Wind Coordinating Collaborative (NWCC)
Operations and maintenance (O&M)
Pacific Northwest National Laboratory (PNNL)
Post-construction fatality monitoring (PCM)
Resource selection function (RSF)
Rotor-swept zone or area (RSA)
Smart curtailment (SC) or bat smart curtailment (BSC)
Structured decision making (SDM)
Supervisory control and data acquisition (SCADA) system
Turbine Placement Zone (TPZ)
Ultrasonic Acoustic Deterrent (UAD)
United States Department of Energy (DOE)
United States Department of Fish and Wildlife Service (USFWS or the Service)
United States Geological Survey (USGS)
Unmanned Aerial Vehicle (UAV) or System (UAS) – aka, drone
Very High Frequency (VHF)
Weather Research and Forcasting (WRF) Model
Wind energy area (WEA)
Wind Integration National Dataset (WIND)
Wind Working Group (WWG)

Opening Session: Celebrating Progress and Setting Future Wind-Wildlife Research Priorities

Speakers:

- **Abby Arnold** – Executive Director, American Wind Wildlife Institute
- **Taber Allison** – Director of Research, American Wind Wildlife Institute
- **Robin Gregory** – Senior Research Scientist, Decision Research and University of British Columbia, IRES
- **Philip Halteman** – Ecologist/Decision Analyst, Compass Resource Management Ltd.

Link to Recording: https://wwrm2020.brand.live/c/live-wednesday

Abby Arnold – Welcome

Since the National Wind Coordinating Committee (NWCC) first convened in 1993, the wind wildlife community has narrowed the focus of research, developed scientifically accepted methods to answer questions, and produced and published research results that are being applied on the ground today. Now tools are available, including sophisticated GIS mapping tools and resources, to inform siting decisions. Searchable databases, including literature and reports related to wind energy and wildlife in North America, are now publicly available, enabling researchers to identify patterns and variations across wind projects. The community has begun to harness artificial intelligence to help minimize impacts through detection and deterrence technologies and better-informed operating strategies.

There is a recognition regarding how wind development – combined with stresses from all anthropogenic activities, including the complicating effects of a rapidly warming climate – can pose a challenge to the resilience of habitat-sensitive species. There is still a lot more to learn about how to avoid, minimize, and compensate for unavoidable impacts, with meaningful results, at price points that keep renewables financeable. The community's success depends on collaboration based in facts and transparency – and on leadership within and across sectors. Experts do not always agree, but this community has been able to achieve results.

Over the past two decades, the NWCC has provided an example for others, including AWWI – bringing stakeholders together for learning, discussion, and relationship-building. From the beginning, NWCC has been supported by the U.S. Department of Energy, through the National Renewable Energy Laboratory (NREL), which is one of this years' sponsors. At the end of 2020, DOE is retiring the NWCC brand, but its role will now be taken over and carried forward by AWWI.

Taber Allison – Introduction

In the closing session of the last (2018) Wind-Wildlife Research Meeting we asked – given the greenhouse gas reductions needed to mitigate climate warming in the next 15 years, and the unprecedented scale of wind energy development needed to meet those goals – what research priorities should we be focusing on over the next five years. The urgency has only become more apparent, and our goals for wind energy development in the coming decades has grown. The challenge of identifying and addressing cumulative impacts as we transition to scaled-up renewables is one of the largest we have faced as a community. How do we best identify and prioritize the research needed to support this challenge?

To help us think through this question, we have invited Robin Gregory and Philip Halteman to start this research meeting with an overview of **structured decision making (SDM)**, an approach to making good choices in the face of uncertainty. SDM has been widely applied to natural resource issues, including by the U.S. Fish and Wildlife Service, but as yet has rarely been applied widely to addressing wind-wildlife conflicts. How can we use SDM to prioritize research that will address the interests of our diverse wind-wildlife community, and support the transition to a clean energy future while conserving wildlife?

Robin Gregory & Philip Halteman – Planning the Future of Wind-Wildlife Research

As Taber and Abby have indicated, the next decade is absolutely critical for wind energy, wildlife, and the habitat and policy spaces where they intersect. We can have sometimes very heated discussions about alternatives, trade-offs, cumulative effects, uncertainty about the magnitude of consequences. Structured decision making (SDM) can help to make those discussions more productive, by keeping the science front and center while providing a safe and comprehensive forum for the discussion of values and an analytic framework for keeping those values in perspective.

Why do we think SDM might be helpful?

Structured decision making is well-suited to helping us answer the types of questions that come up at the nexus of wind energy development and wildlife conservation, because it helps groups work through choices that require an understanding of both facts and values, and navigating trade-offs.

There is nothing mysterious about the SDM process; the key is that it requires us to articulate clearly the answers to a series of common-sense questions:

- ***Context*** – *What are we really deciding about?*
- ***Objectives*** – *What do we want?*
- ***Alternatives*** – *What can we do?*
- ***Consequences*** – *What will happen?*
- ***Trade-offs*** – *What do we prefer?*
- ***Monitor*** – *How can we learn and adjust?*

SDM keeps us from making the mistake of assuming everyone has a common understanding of the context and objectives going in.

In particular, SDM dives deeply into **context** and **objectives**. Gaining clarity on what it is we are really deciding about and a better understanding of the values at play in a choice almost always allows new alternatives to emerge. Visible focus on values also helps build a base for wide-spread support; values are put explicitly on the table, so that different groups are able to see their interests incorporated. SDM also explicitly represents uncertainty in ways that clarify consequences and associated risks and help to identify the most important knowledge gaps. This leads to better dialog about risk, uncertainty and trade-offs.

The “magic” of SDM is iteration. The process captures what is learned about trade-offs to clarify objectives, and creates better alternatives both by clarifying the context and objectives and by incorporating new information as we refine estimates of consequences. By improving the quality of deliberation, SDM not only promotes learning and facilitates better choices, but it offers insights that can lead to broad agreement on priorities from the public, experts, and regulators.

Examples of SDM applied to management of wildlife impacts:

- ***Case #1 - Big societal benefits being weighed against poorly understood risks.*** In this case, biologists were in disagreement about what a mining project's impacts would be on a nearby caribou herd. SDM helped them to: (1) articulate the cause-and-effect linkages that most concerned them; and (2) weigh evidence for various hypotheses about those linkages and possible effects. The structured and rigorous process enabled them to separate the values aspect of risks from their technical understanding of those risks. This helped to clarify where exactly they were in disagreement about the effectiveness of various proposed mitigation measures. Highlighting these critical uncertainties allowed them to develop an adaptive management strategy designed to improve understanding of the risks over time, and incorporate new knowledge into the management approach.
- ***Case #2 – Decision sketch: getting a better idea of the main drivers of a problem.*** In the case of a "failure to recruit" among a population of white sturgeon in the Upper Columbia River, scientists trying to understand the problem had come up with more than 200 hypotheses, but were stuck trying to narrow the field to a manageable research plan. A structured "decision sketch" approach allowed the group to eliminate about 80% of the hypotheses using three questions: (1) What percentage of the problem is attributed to this hypothesis, based on current knowledge? (2) How certain are you in making this assessment; and (3) How important is it to resolve this uncertainty? The results of this exercise were represented by a diagram that grouped the hypotheses into quadrants as a function of certainty and importance. Candidates considered "certainly" important ranked highest for action, but only "moderate" as research priorities; high-certainty low-importance hypotheses were in the "low priority" quadrant; the highest priority for research were those hypotheses considered important in terms of impact but also highly uncertain.

In the case of wind energy development and wildlife issues, SDM can help stakeholders compare alternatives in terms of multiple attributes: wildlife risk, mitigation costs, electricity production, greenhouse gas reduction benefits, and any other societal costs of benefits that need to be considered. Creating a "consequence table" organizes the knowledge we have in terms of the things we value (wildlife, electricity, reducing climate change). It may quickly become apparent that some of the alternatives we are considering are clearly inferior. It also highlights those knowledge gaps where more information or a clearer understanding would make a decision clearer. Again, SDM both frames and helps to communicate the most important drivers of a given decision.

How move from the work of a smaller group to get buy in from a larger community?

All 400 people don't have to be in the room; for example, a group of 10-20 people who represent much larger groups or interests might meet every other week. In between meetings, however, each of those people on the committee is reaching out to their constituents and getting their input. (Surveys, media, town-hall meetings, etc. can also be used to gather larger stakeholder input.) Research doesn't help unless it makes a point of identifying and addressing what people care about.

To this point: stakeholders matter. Context matters. Social, health, and cultural values matter. Structured decision making explicitly recognizes this, and with it that the relative importance of the benefits, costs, and risks of wind power and impacts on wildlife will vary across different contexts and stakeholders. (Some regions, for example, will have well-formed groups in support or in opposition to a specific wind power proposal, whereas others will not.) And of course, uncertainty matters. The better we can represent uncertainty and trade-offs explicitly, the easier it will be for stakeholders and experts to arrive at a way to move forward.

Can SDM help with "decision fatigue"?

There are a lot of people in the wind/wildlife community who have been having these discussions for a long time. Fatigue comes from not seeing a path forward. Something as simple as a decision sketch exercise can help clarify the problem context. It entails a relatively quick run-through of the first several steps to arrive at understanding of the frame of the decision: the key values at play, realistic alternatives, sense of likely trade-offs. This usually can help a group get "un-stuck" over the course of a few meetings. Seeing the process helps people refocus so that they can see a path forward, building on what the group has already done.

Methods for Reducing Bat and Eagle Impacts from Wind Energy

Moderator: Amy Parsons – Operations Wildlife Compliance Manager, Avangrid Renewables

Speakers:

- **Chris Farmer** – Senior Ecologist, Western EcoSystems Technology, Inc. (WEST)
- **Jonathan Rogers** – Chief Technology Officer, Persimia, LLC
- **Sara Weaver** – Senior Ecologist, Bowman Consulting
- **Adam Duerr** – Research Wildlife Biologist, Bloom Biological, Inc./Conservation Science Global, Inc.

Link to Recording: https://wwrm2020.brand.live/c/live-wednesday

This panel focused on the state of science and application of available technologies and techniques for predicting and reducing collision impacts to eagles and bats. Panelists presented updates on: collision risk modeling for eagles at landscape and project-specific scales; the use of detection technology as part of a detection and deterrent strategy for eagles; recent findings and ongoing research on the effectiveness of acoustic deterrents for bats; and an approach to optimizing curtailment to minimize energy production loss for any given level of bat fatalities.

Discussion focused on:

- Factors operators need to consider when evaluating use of strategies currently available on the market and operational challenges to implementing technologies on turbine platforms
- Nature of optimization and operations & maintenance challenges/opportunities for risk reduction solutions
- Research gaps and evidence of risk reduction effectiveness

Chris Farmer – Eagle Collision Risk Modeling

See also on-demand presentation #111: Quantifying Turbine-Level Risk to Golden Eagles Using a High-Fidelity Updraft Model and a Stochastic Behavioral Model.

USFWS' Collision Risk Model (CRM) helps us predict how many eagles are at risk at a wind farm, but we rely primarily on expert opinion for the temporal and spatial risk factors: *when* and *where* these birds are at risk. Using what we know about the physics of eagle flight and the kinds of complex models used in project wind energy assessments, we can make more objective predictions of flight behavior and patterns based on inputs we can directly measure. Initial attempts to test these predictions suggest that terrain-generated (orographic) updrafts provide a good qualitative predictor of collision risk; however, there are too few fatality data points available to validate that approach.

A new effort led by NREL with assist from WEST and USGS deploys terrain- and weather-based modeling tools to help us understand risk at the regional level (mesoscale) to inform siting decisions, as well as at the local/site level (microscale) for predicting risk at a project. This is intended to augment, not replace, the USFWS CRM. (See Eliot Quon – Atmospheric Modeling to Enable Prediction of Golden Eagle

Interactions with Wind Power Plants, and on-demand presentation #111: Quantifying Turbine-Level Risk to Golden Eagles Using a High-Fidelity Updraft Model and a Stochastic Behavioral Model)

- Mesoscale tool – provides, for any area in the U.S., the spatially explicit probability that eagles are flying at conflict-producing heights. Combines terrain models, thermal and orographic updraft modeling. By adding instantaneous thermal updrafts to the model we can see that the environment encountered by eagles in real time is much more variable than what we would see under time-averaged conditions. This would explain why modeling using time-averaged updraft conditions has given us reasonable but not great fits. (See on-demand presentation #94: High-Fidelity Modeling of Eagle Soaring Habitats Near Wind Plants in Complex Terrain, for a more detailed presentation.)

- Microscale tool – leverages the same updraft modeling approach to model changing risk within a wind farm under different weather scenarios (temporal as well as spatial) risk. Will use machine learning trained on telemetry data, energetics limitations and other inputs to produce spatial distribution of risk within a wind farm.

Jonathan Rogers – Optimization of Curtailment Algorithms

See also on-demand presentation #28: Optimal bat curtailment: A data-driven strategy to sustain bat populations while minimizing curtailment losses.

The use of data to optimize decision making can be applied in a wide variety of fields. In this case, I've been looking at adaptations of smart curtailment algorithms to minimize energy production losses without exceeding acceptable levels of bat fatalities.

"Blanket" curtailment reduces fatalities by increasing the cut-in threshold, or wind speed at which turbines start to generate energy. Smart curtailment bases the cut-in decision on multi-variable risk factors (e.g., temperature as well as wind speed). The objective of these curtailment regimes is simply to minimize bat fatalities, with the understanding that there is a trade-off between that goal and the goal of minimizing lost energy production. An "optimal" curtailment algorithm is based on the premise that we can establish an acceptable threshold (or "fatality budget") that sustains bat populations of a particular species. While there is still a trade-off, an optimization approach means that energy loss is minimized for any given level of bat fatalities.

Bat fatalities are a function of many factors: wind speed, temperature, time of night, season, etc. An optimal curtailment scheme drives annual energy production (AEP) losses down as low as possible by thinking about predicted revenue from turbine activity during a given time period, and predicted bat fatalities during that same period as trade-offs within the maximum acceptable "bat fatality budget" constraint. For example, if we would expect to see similar levels of bat activity and fatalities during two different periods, but the model predicts higher expected revenue for one of those periods, we would curtail preferentially during the period with less impact on AEP.

Sara Weaver – Ultrasonic Acoustic Deterrents to Reduce Bat Fatalities

Recent research testing ultrasonic acoustic deterrents at a Duke Energy Renewables facility in S. Texas found that the deterrents resulted in a 55% fatality reduction for Brazilian free-tailed bats, 78% for hoary bats. It was not successful for the Northern yellow bat, which highlights the question: why are acoustic deterrents effective for some species but not others?

A diverse group of collaborators currently is working on a DOE-funded study to better understand these differences and optimize the NRG deterrent system. The study uses an outdoor bat flight cage large enough to fit a 60-m wind turbine blade. Using acoustic detectors and thermal monitors to track echolocation and flight behavior, respectively, we can look at different species' responses to acoustic deterrents, including variations on the original NRG technology. (See on-demand presentation #31: Preliminary results on effectiveness of an ultrasonic acoustic deterrent from bat flight cage trials.)

Adam Duerr – Detection and curtailment system for eagles

Research looking at risk from renewable energy development to large soaring birds – primarily golden and bald eagles – involves understanding their behavior, and what factors influence when, where and how they fly. The performance of IdentiFlight, a technology system used to detect, track, identify, and initiate curtailment for large birds (in this case golden eagles) was assessed at the Manzana wind energy facility in California. The IdentiFlight system includes eight fixed cameras scanning 1000 m from the IdentiFlight tower. Wide field-of-view cameras detect flying targets; high-resolution stereo cameras are used to identify the target and – if it is identified as an eagle – then track it. If the system determines that an eagle is at risk of collision, it issues an order to the SCADA system to curtail. Curtailment orders were issued but not actually implemented for this research project.

Audience Questions & Panelist Response/Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- In terms of technology-based solutions, how balance effectiveness with "keeping it simple" to implement?
- For curtailment strategies, how balance competing objectives? E.g., trade-off between lost production (false positives) and wildlife fatalities (false negatives)? Do we know enough to establish bat "fatality budgets" so as to optimize curtailment?
- What are some of the key implementation challenges we need to address, and what research is being done in these areas?
- What are the pressing biological questions we need to answer, and what research is being done in these areas?

From a project operator's perspective, the mantra is "keep it simple." When it comes to the technology solutions considered here, what are the trade-offs in terms of efficacy (minimizing loss of both wildlife and energy production) and operational simplicity? *Panelists commented on this question with respect to curtailment optimization strategies; predictive modeling; and the use of detection and deterrent technologies.*

Curtailment optimization. Curtailment strategies to minimize bat fatalities can be thought of on a continuum: from blanket curtailment (raising the cut-in speed) to a simple "smart" curtailment model (using wind speed thresholds) to detection-based smart curtailment (using echolocation monitors to detect bat presence near the risk zone) to a more sophisticated curtailment model that factors in the risk of both bat fatalities and energy production losses. Any strategy that requires additional hardware (e.g., acoustic detectors) and an interface with the SCADA system is more operationally complex than a blanket increase in the cut-in speed, but has the advantage of reducing unnecessary energy production losses. Current smart curtailment approaches lack flexibility; folding in all the sources of data – including financial as well as fatality factors – allows us to achieve the same fatality reductions in a budgeted way that minimizes power loss. There is greater complexity in the modeling, but not necessarily in the implementation.

Predictive modeling. From a curtailment perspective, simple models (e.g., just wind speed) tend not to predict very well; they result in a lot of false positives. A more complex predictive model could result in a more optimal solution without being more complicated to implement in terms of wind facility operations. Such predictive models require an upfront investment, however, and there remain questions about how site-specific such predictive models need to be, and how many years of data are needed to develop them.

Detection and deterrent technologies. Technologies to detect and deter eagles and bats involve mounting equipment on the turbine tower, nacelle or blades or other infrastructure such as met towers. From an operational standpoint, it would be preferable if such equipment could be built in by the manufacturer rather than retrofit. Some types of equipment (such as acoustic detectors) are not difficult to mount, other types of equipment pose greater installation and O&M challenges, and in some environments may wear out and need to be replaced. Deterrent systems have the advantage that they do not require curtailment (hence no SCADA interface and no loss of energy production). Deterrents also could be used in combination with a curtailment optimization strategy to further reduce energy production loss for a given "acceptable fatality" budget.

For curtailment strategies, how do we balance competing objectives? Panelists commented on the causes and costs when a system produces false positives, and on the implications for system operators of false negatives. Panelists also discussed whether we know enough to establish bat "fatality budgets" so as to optimize curtailment.

False positive vs. false negative trade-offs. From the operator's perspective, false positives carry revenue implications, which can be quite heavy. False negatives may also impact revenue if they lead to penalties and regulatory constraints. The key to "optimal" curtailment is to look over a yearly time-horizon and use long-term forecasting to predict high and low wind/revenue periods as well as predicted bat fatalities. Establishing a "bat fatality budget" allows operators to take into account both the variation in rewards (revenue, avoided fatalities) and costs (lost revenue, dead bats). This requires forecast data to make optimal decisions for a particular site.

How to determine the "acceptable" bat fatality loss? The optimization strategy requires establishing an annual bat fatality budget, or acceptable level of losses, for a given project. This raises several questions: Does/should the "acceptable loss" limit consider cumulative risk to bats from other threats? Unlike eagles, where we have a fairly good understanding of populations, we have little information about bat population sizes, and therefore what constitutes the minimum sustainable viable population. (Jon points out that, as long as there is a non-zero number of acceptable losses from a population standpoint, there is an opportunity to optimize curtailment with respect to a given species for a given site.)

What are some of the key implementation challenges we need to address, and what research is being done in these areas? Panelists addressed this question with respect to deterrent technologies, improving detection technology performance (eagles), and the application of technology solutions in the offshore space.

Deterrent technologies. For bats, there are different types of acoustic deterrents, and two main mounting strategies: blade-mounted and nacelle or tower-mounted systems. Blade-mounted deterrents include a piezoelectric system that generates ultrasonic signals; and a whistle that creates an overtone from the blade movement. There have been some mechanical challenges with the piezoelectric system, which is still in the works; the results not yet available for the whistle device. Nacelle and tower-mounted systems include the piezoelectric type and a pneumatic-powered ultrasonic jet. These deterrents have been tested on 55-m blades, so there remains some question as to whether they will remain effective on modern turbines, with 65- to 70-m blades. Bats seem to respond to sounds at 55 dB. At 40 & 50 kHz, the sound may not be loud enough to be heard beyond tip of a 55 m blade. Flight cage studies will shed more light on these questions.

Improving detection (for eagles). The IdentiFlight system continues to be refined; during the one-year test at Manzana energy project, training data was increased a couple of times to make improvements. Some research has found that IdentiFlight compares favorably with human observers when it comes to detection, but is still not as good as we would like at identifying species. IdentiFlight does better in areas where there are fewer confounding species. (The abundance of ravens at Manzana site, for example, led to higher rate of false positives than at a Wyoming project site where ravens were less abundant.) This indicates that it's important to train the system not just on the target species but on distinguishing the target species within the community of species around a given facility. The Peregrine Fund is interested in using IdentiFlight to develop different models for predicting and reducing collision risk at individual turbines. NREL's microscale tool is likewise being developed with the idea of understanding the optimal place and time to deploy curtailment.

Risk to bats in offshore space. Panelists were asked what research priorities pertain to the question of bat fatality risk/energy output trade-off for offshore wind energy facilities. Understanding collision impacts from offshore wind energy facilities is complicated in that we cannot look for carcasses on the ground. Technology such as cameras and impact detection systems are needed to know whether and how many fatalities are occurring. Such technologies offer the promise of providing data about when and under what conditions fatalities occur, which is necessary for building and validating risk prediction models that would support optimization of curtailment strategies.

Use of technology to improve carcass detection: While essential in the offshore environment, cameras, impact detection and other technology (such as drones) also could be used to improve on current fatality search methods at terrestrial wind facilities. In particular, technologies that provide the time of collision would help researchers to better understand relevant risk variables. There are multiple investigations underway, including turbine-mounted as well as less expensive, easier-to-install ground-based systems; it is not yet clear what's going to be most effective.

What are the pressing biological questions we need to answer, and what research is being done in these areas? Panelists addressed the need for understanding how different species respond to deterrents, population questions, and learning from GPS-tagged eagle data.

Species-specific deterrent effectiveness. For bats, we are still in early phases of research into deterrent technologies. Acoustic deterrents appear to be more effective for some species than for others, yet the frequency range of the system (typically 20-50 kHz) spans the range of most bats we might be concerned about, so it is not clear that would account for why some bats are deterred and others are not. Bats may adjust their echolocation frequencies, and it's possible that (for example), males are not as easily deterred as females during the mating season. That said, a deterrent that works for females during the breeding season may suffice to stabilize population size for that species.

Understanding how the physiology of different species affects individuals' ability to sense potential deterrents is critical. For eagles, some recent physiological research suggests that they are more likely to respond to auditory than to visual stimuli. An evaluation of the DT Bird system suggests 30-50% effectiveness for golden eagles; this is a hopeful result, but more needs to be done before it is ready to be deployed. For night migrants, a lot of the sensitivities are species-specific, so it is not as likely that one deterrent would work for a broad range of species. Night migrants are less susceptible to collision when flying than during landing and take-off, so it may be that approaches other than deterrents would be more suitable.

Attraction hypothesis (bats). Analysis of video shows bats engaged in risky behavior around turbines, leading to the "attraction" hypothesis. We don't know whether bats see turbines as trees (roosting habitat), whether they're foraging because there are insects there, or perhaps the turbines are putting out magnetic signals? Video from a South Texas facility showed bats investigating the MET tower and anonometers as well as turbines, providing support for the tree hypothesis. Anonometers also have rotating blades, and we know that bats also get killed by ceiling fans, so it may be there is something about the rotation that is attractive (and that vertical vs. horizontal axes don't matter). Some results are expected soon from testing the use of UV light to discourage bats from being attracted to turbines by helping the bat to "see" that the turbine is not a tree.

What we are learning from tagged eagle data. Data from GPS-tagged eagles provides a lot of information about habitat use in three dimensions, helping us understand how environmental factors (such as topography) contribute to flight altitude and therefore to collision risk. GPS data also help us understand finer scale movements and how weather patterns affect behavior, and give us travel speeds for different altitudes, so that we can fine-tune "time to collision" for curtailment decisions. While we do not know how representative of the population the subset of GPS-tagged individuals is, modeling based on these data, along with what we know about the biological and physical drivers, tells us more about general principles.

Conclusions

Emerging collaborations are creating and taking advantage of opportunities to reach better solutions. Other research to determine the additive effect of deterrents with curtailment would be helpful; the more tools in the tool box, the better. We need to be looking at the effectiveness of these tools with different species, at different project sites. We need to identify proxy species that are not as rare, in order to test effectiveness for rare species.

Recommended Resources

- E. Fernandez-Juricic et al., 2020. Understanding the Golden Eagle and Bald Eagle Sensory Worlds to Enhance Detection and Response to Wind Turbines.
- J. Smith et al., 2018. Evaluating a Commercial-Ready Technology for Raptor Detection and Deterrence at a Wind Energy Facility in California.
- C. McClure, 2018. Automated Monitoring for Birds in Flight: Proof of Concept with Eagles at a Wind Power Facility.
- K. Nielsen, D. Young, S. Webster, 2019. Guidance for Potential Host Sites of Wind-Wildlife Technologies and Strategies.

- K. Nielsen, 2018. Integration of Wildlife Detection and Deterrent Systems in Wind Power Plants.

Aerial Eagle Nest Surveys: Alternative Approaches and Recommended Best Practices

Moderator: Tim Hayes – Director, Environmental, Duke Energy Renewables

Panelists:

- **Sean Fitzgerald** – Project Manager, Environmental Services, NextEra Energy
- **Shawn Childs** – Senior Environmental Analyst, PacifiCorp
- **Adam Kreger** – Senior Specialist, Wildlife and Environmental, Clearway Energy
- **Jerry Roppe** – Principal Biologist, Avangrid Renewables

Link to Recording: https://wwrm2020.brand.live/c/live-wednesday

The Aerial Eagle Nest Survey Task Force is a diverse group of individuals from the wind industry and biological research consulting firms convened by the American Wind Energy Association (AWEA) in 2020 following two fatal accidents involving wildlife biologists and pilots conducting eagle nest surveys for wind projects. Task force members consulted with experienced wildlife survey pilots. Eagle or other raptor nest surveys are often recommended by the U.S. Fish and Wildlife Service for Eagle Conservation Plan development and/or are required by state wildlife agencies for state permitting. Nest data requirements will only increase along with wind development; methods for safer, more effective, and more efficient nest data collection could improve industry standards and the safety of people gathering this data.

A series of white papers have been drafted. While this panel focused on alternative approaches, Moderator Tim Hayes first reviewed key best safety practice recommendations for manned aerial surveys:

- Manned aerial surveys should be the last option considered
- Everyone who is participating should know the risks and take them willingly
- Stop-work authority for all crew members, even during the mission
- Use experienced low-altitude pilots
- Maintain the maximum altitude possible to complete the mission
- Crew resource management – everyone (crew and researchers) should be trained on cockpit procedures.
- Minimize time in the air and number of trips
- Gather only necessary data (identify nest structure and active occupancy)

Key resources include guidance used by utility aviation specialists as well as practices used for low-level manned aerial surveys as part of the USFWS Migratory Bird Program.

Sean Fitzgerald – Science and Data Needs for Eagle Nest Surveys

Why survey eagle nests during project siting? The USFWS' Eagle Conservation Plan Guidance (ECPG) considers nests "Important Eagle Use Areas" and calls for "scientifically rigorous surveys" designed to assess a proposed wind energy project's potential risk to eagles, including the risk of: direct collision; nest disturbance; and loss of nesting territory. Specifically, the ECPG calls for determining "the number and locations of occupied nests and the approximate centers of occupied nesting territories within the project area." These data are used to inform turbine siting and are the primary quantitative tool used to inform fatality predictions. (While nest surveys may flag the potential for nest disturbance, there is no empirical data as yet about disturbance impacts from turbine operation.)

Along with historic nest location data, surveys of the project area and a 2-mile buffer should provide data on occupied as well as unoccupied nests (which may become occupied in some years) and areas where nests do not occur, all of which can aid in turbine siting, construction timing, and seasonal restriction buffers. Occupancy status is important for gauging which nests are currently active and more likely to have consistent eagle use, but nest productivity checks should be minimized – both for the safety of researchers and for the productivity of eagles.

The Mean Inter-Nest Distance (MIND) calculation developed by USFWS should no longer be used to determine important eagle use areas. The USFWS' updated recommendation is to conduct field surveys for eagle nests only within two miles around the project footprint. This distance was based on telemetry data from 101 adult golden eagles at active nests; bald eagles typically have a smaller home range, so the 2-mile limit is likely to be more than sufficient.

The National Bald Eagle Management Guidelines (USFWS 2007) recommend a 660-ft buffer zone for project activity around bald eagle nests to avoid disturbance. There is no national guidance to date for golden eagles, but there is some regional guidance. In terms of maintaining a buffer distance for conducting aerial nest surveys, there is no consensus for either manned or unmanned aerial surveys, so this is an area where more data is needed.

Measures to "avoid" and "minimize" project impacts should be informed by eagle nest surveys. The Task Force recommends:

- Minimum of one year pre-construction eagle nest survey – gather prior nest information first, then do two site visits: one in Feb-Mar to locate all suitable nest structures, and the second in Apr-early May to ascertain occupancy status (timing of these visits may vary based on the project location). A second year of surveys may be warranted, especially if there is a gap of more than one year between the first nest survey and beginning of construction.
- Decouple non-eagle raptor nest surveys from aerial eagle nest surveys to minimize aerial survey time and risk. Don't spend extra time looking for red-tailed hawk data when this information is not important to decision-making about eagles. The practicality of this varies widely among projects and states as other raptor species of conservation concern may have their own implications for a project.

Shawn Childs – Ground Based Eagle Nest Surveys

The Task Force's Ground-based Eagle Nest Survey team developed best management practices for ground-based eagle nest surveys.

- Planning is critical. Consult with USFWS first to determine whether surveys are necessary, based on project size and location. Are there established protocols in the region? Are there any additional objectives? Per USFWS' updated recommendations, limit the size of the survey area.
- Desktop analysis can be used to identify the location of known nests within the survey area and to focus on suitable eagle nest habitat, reviewing access and viewpoints for both known nests

and suitable nest habitat. Consider alternatives to accessing known eagle nests. Can drones be used to survey these areas? Develop and review the survey protocol with relevant agencies. Contact owners or lessees about land access areas adjacent to project.

- Survey Implementation and Safety – A detailed and comprehensive safety plan should be reviewed with the developer and contractor. It should list all the job hazards and include emergency contacts and exit routes. Ask local emergency services about known hazards, and give them a copy of your plan. Monitor weather and roads for a few days prior to the survey, and be prepared to alter the plan if needed. Use two searchers, especially if someone is driving!
- Carry season- and region-specific emergency supplies. Surveys should be conducted under good light and visibility conditions (no rain, snow, fog). Let landowners and lessees know when searchers will be on the property, carry an authorization letter and business card. Put the company logo on the vehicle, and make sure company contact info and work description is visible through the windshield when the vehicle is parked. If possible, conduct observations from within the vehicle. Maintain physical distance from occupied nests.
- Confirm nest location and occupancy quickly, minimize disturbance to occupants, and keep nest locations confidential. Limit the number of trips by combining non-eagle raptor nest searches with eagle nest searches. Although it is not always possible, use all-ground-based surveys wherever possible.

Adam Kreger – Eagle Nest Surveys Using Drones – a Promising Alternative to Conventional Aircraft

Unmanned aerial vehicles (UAVs or drones, sometimes also referred to as UAS, unmanned aerial systems) offer a promising alternative to eagle nest surveys using conventional aircraft. A 2003 paper identified 66% of all wildlife biologist fatalities resulted from manned aircraft incidents. Inclement weather often makes these reconnaissance flights more risky. At the same time, there are nests that can be seen from the air that cannot be seen from the ground. There is consensus that drones are safe, fast, economical, and cause minimal disturbance to wildlife. Drones have been used to survey: osprey, bald eagle, ferruginous and red-tailed hawks, and other species.

As with using helicopters and other manned aircraft, there are regulatory considerations for using drones. FAA Part 107 provides for obtaining waivers for flight plans that deviate from the normal rules. Disturbance of nesting raptors is prohibited by several statutes, including the Airborne Hunting Act, but drones are quieter, and less likely to disturb birds than a large noisy helicopter. (Helicopters elicit stronger disturbance reactions than fixed-wing aircraft, but studies have reported no significant or long-term impacts in terms of nest abandonment or reduced nest productivity.)

Drone pilots need to be FAA-certified and trained, and should shadow a more experienced remote pilot conducting nest surveys using UAV. As with manned aerial surveys, a biologist should be working alongside the UAV pilot, directing observations and helping inform the pilot to minimize potential disturbances. Best practices include approaching the nest from an angle rather than head-on, using appropriate cameras, collecting data from the maximum feasible distance. UAVs should be launched from outside a buffer zone, and any hovering or abrupt maneuvers should be minimized. (See Junda et al. 2015 for detailed raptor nest check protocol using UAVs.)

Capabilities vary with the model. One of the larger systems provides a 5 km unobstructed range, flight time of 10-45 minutes, top speed of 18 m/s, and a payload of up to 6 kg. (The smaller the payload, the longer the flight time.) Fairly light-weight cameras providing high resolution, zoom or thermal imaging capabilities are available. The cost of a drone is $200-300/hour (compared with $650-1200/hour for a helicopter). While drones have not been used for pre-construction eagle nest surveys to date, they have been used successfully for nest monitoring. So far no disturbance has been reported when drones are flown >50 m above ground level.

For nest surveys, where drones are appropriate, recommended best practices include:

- Survey early in the nesting season and in favorable weather
- Minimum of two personnel (pilot and observer)
- Create a flight plan in advance
- Land or retreat immediately if the UAS is approached by a raptor
- Launch at least 100 m from known nests
- Fly as high as possible to minimize disturbance
- Approach nests from an angle, and never from directly overhead
- Minimize hovering and abrupt maneuvers

The technology is ready, drone operators and developers are ready to use it. Drones are safer, less expensive, and more effective for doing follow-up surveys and nest productivity monitoring.

Jerry Roppe – The Decision Process and Putting It All into Practice

The Task Force Synthesis Group created an Eagle nest survey decision tree (slide) for developing a survey plan, providing a “job hazard assessment” at each decision point. There is not necessarily a single solution; the decision tree facilitates balancing risk through the consideration of various survey approaches. Are surveys required, or are existing/desktop analyses enough? What can be done with ground-based surveys? Can UAVs give you what else you need? The decision tree allows developer and contractor to document the survey protocol, and provide a rational basis for decisions, requiring justification for any manned aircraft surveys still needed. It references the Safety Task Force white papers in developing a survey protocol.

A final step is to conduct a post-survey safety review to assess the protocols and the outcomes. Were there near misses? Are there any “do-overs”, or “do betters”? This analysis can be incorporated into decision-making and protocols going forward. The Task Force recommends that industry make use of the decision tree and white papers both for internal work and when contracting with other firms to conduct surveys.

Audience Questions & Panelist Response/Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- Do recommended eagle nest survey safety practices meet USFWS survey protocols?
- How do these recommended survey approaches compare in terms of cost?

Do recommended eagle nest survey safety practices meet USFWS survey protocols? *Given that there were no research scientists or agency management decision makers on the Task Force, how sure can we be that this meets their needs? Has the Service approved the use of UAVs for this purpose?*

USFWS Survey Protocols. None of the Task Force's safety recommendations directly conflict with FWS survey protocol recommendations. In developing their recommendations, the Task Force sub-groups reached out to research scientists, and the consultants who do the work out on the ground (and in the air). Consultation with the agencies is part of developing the protocols, regardless. It's important to talk through the survey methodology and scope with the relevant resource agencies and wildlife biologists, to communicate early and to get their input (what data do they really need?) and their buy-in as to how to get that data safely.

Have alternative survey methods been approved? The USFWS has not yet formally approved the use of UAVs for nest surveys. But the Wind Energy Siting Guidelines don't specify manned vs. unmanned aircraft use for surveys. Part of purpose of this panel is to generate more discussion. (Moderator Tim Hayes encouraged USFWS personnel to weigh in.) Drones are being used quite a bit now as "part of the operations & maintenance toolkit" – e.g., for blade inspections, as well as for pre-construction design surveys. These uses have not come up expressly with USFWS, because they are not being used to meet the Service's requirements.

The USFWS has approved the use of ground-based nest survey methods. Such alternatives are easier to use in the Midwest, where there are long sight lines and good road access, as opposed to areas with dense forest or deep canyons.

What about the Airborne Hunting Act? USFWS has ruled that use of UAVs violates airborne hunting act, but it depends on how the drone is being used, and what precautions are taken to avoid disturbance. The issue of disturbance applies to manned aerial surveys, as well as to drones. In both cases the key is to follow best practices (distance, angles, having a biologist observer with your pilot).

How do these recommended survey approaches compare in terms of cost? *Aerial surveys are expensive, but if it takes a lot longer to cover the project area with a ground-based or UAV approach, might that increase costs? Will industry be willing to embrace these safer alternatives?*

The wind industry was well-represented on the Safety Task Force, which suggests that most wind companies recognize that, even if it does cost more, you cannot put a price on human safety. In addition to the individual white papers, the decision tree helps project managers to document why safety protocol decisions are being made; it's a good tool for communicating the rationale to upper management that may be far from the biologists. Likewise, it helps to incorporate safety considerations into request-for-proposal language when hiring consultants to do this work.

How long to survey with drone vs. helicopter? Helicopters can cover a large area in fairly short amount of time, but there is risk with that, so it is never just a matter of the cost in terms of time. Helicopter flight time is much more expensive, so it is likely that using a UAV would save in terms of cost, even if it takes longer to conduct the surveys. Depending on the size of the project area, the time factor may matter, given that surveys need to be conducted during a finite nesting period. Again, the value of the decision tree is that it helps you to look at your specific project area and data needs, and determine what types of survey methods will get you that data. Having looked at what you can get with ground-based and UAV surveys, you may find that you do not need a helicopter, or that you don't need it as extensively.

Other questions

Could Lidar be used to identify nests, followed by checks to determine their status? Lidar (a remote sensing method) could be an initial screening tool, suggesting where to look for nests, but cannot be relied on. In some cases, likely nest sites have been identified from ground-based surveys, and the nest then found and examined using Google earth satellite images. Unlike ospreys, bald eagle nests tend not to be out in the open, but down in the canopy, where they may not be visible from satellite imagery. Some projects in the Eastern U.S. have found nests during winter and early spring when leaf cover is relatively low, but it requires high resolution imagery.

Are aerial surveys recommended for looking at communal roosts for bald eagles? The time window for surveying communal roosts is very narrow – at dawn and at dusk each day – which is ill-suited for aerial surveys. The location of most big communal roosts tend to be reasonably well known to state wildlife agencies, Audubon groups, landowners. They also can be found from the ground by following the direction of eagles flying at dawn and dusk.

Technology Solutions and Application for Offshore Wind and Wildlife

Moderator: Kate Williams – Wildlife and Renewable Energy Program Director, Biodiversity Research Institute

Speakers:

- **Ricardo Tomé** – Scientific Director, STRIX Environment & Innovation
- **Jennifer Stucker** – Research Biologist, Western EcoSystems Technology, Inc.
- **Trevor Peterson** – Senior Wildlife Biologist, Stantec Consulting Services, Inc.
- **Ruben Fijn** – Team Manager Seabird Ecology, Bureau Waardenburg

Link to Recording: https://wwrm2020.brand.live/c/live-thursday

This panel, consisting of European and American experts on offshore wind energy and wildlife, delved into the state of technology development and applications to address potential wind-wildlife interactions for offshore wind energy. Many methods for monitoring birds and bats in relation to land-based wind energy development are not practical in the dynamic offshore environment. In addition to collision mortality, the known and potential impacts of offshore wind energy development on marine birds in particular may include effective habitat loss via disturbance, indirect effects relating to changes in habitats and prey populations, and migratory barrier effects. As a result, wildlife research and monitoring in relation to offshore wind energy siting and operations relies on a variety of technological solutions.

Discussions focused on:

- Differing approaches to risk assessment in the offshore vs. onshore environments
- Capabilities and limitations of several monitoring technologies, including those under development and evaluation in Europe and the U.S. for onshore and offshore applications
- Challenges and opportunities for integrating monitoring technologies into offshore wind equipment and operations

Moderator Kate Williams began with an overview of key terms and concepts, "Understanding the Effects of Offshore Wind Energy in the U.S. on Birds and Bats" (see on-demand presentation #14: Understanding the Effects of Offshore Wind Energy Development in the U.S. on Birds and Bats: Identifying Key Research Needs, Mitigation Measures, and Conservation Guidance). As with terrestrial wind projects, potential impacts include collision fatalities and habitat-based impacts (e.g., ecosystem and habitat changes, displacement, and avoidance). Turbine bases create artificial reefs that can change local ecosystem dynamics and prey availability. In addition to monitoring the impacts of a given site, some monitoring technologies are designed to gather data to improve estimates for collision risk modeling (or "rate" modeling). In some countries these models are used to predict risk and inform permitting.

Ricardo Tomé – Radar-Assisted Shutdown on Demand

Radar is used both on and offshore to detect and track birds for pre- and post-construction monitoring and for radar-assisted shut-down on demand. It allows us to track multiple individual birds simultaneously across a 7 km-diameter range. We can see where they are relative to the wind turbines, the direction they are flying, and how long it will take them to reach the risk zone. Using radar to detect approaching birds and trigger either automated or manual curtailment of turbine operations has yielded very positive results – near-zero to very low mortality, low energy production loss –at land-based wind energy projects within migratory flyways in Portugal and Egypt.

There is reason to think these technologies would work well in the offshore environment as well. Radar is now being used at a new wind project off the coast of Portugal to assess bird use of both the wind farm area and a control area, and to assess collision risk during project operation.

Monitoring the impacts of offshore turbines on birds can be accomplished with a combination of radar and camera technology. Radar gives us 3D trajectories, including accurate flight height of individual birds, at distances of up to 7 km for larger birds (e.g., Northern gannet), with somewhat smaller birds (e.g., gull) up to a distance of 3 km. We can use this to detect macro- and meso-scale avoidance, and also for sensitivity mapping and strategic planning. High-resolution cameras can play a role in species identification, collision detection, and the assessment of bird behavior at proximity to the turbine (micro-avoidance).

Even with the combination of these technologies, the offshore environment presents some challenges. Collisions are rare events and may involve rare species, which makes it hard to get meaningful samples that allow us to accurately assess avoidance rates at different scales for use in risk modelling. The marine environment constrains the use of technology and especially the use of visual observers to validate data. These limitations increase under harsh weather conditions, which would also influence bird behavior, if most of our data is gathered under good weather conditions, we have to account for that bias.

Jennifer Stucker – Design and Challenges of Developing Offshore Technologies

See On-demand Presentation #63: A Multi-Sensor Approach for Measuring Bird and Bat Collisions with Offshore Wind Turbines.

In designing and developing offshore technologies, what tools we need depends very much on the question of scale – where should we be assessing impacts, and how do we do that in the offshore environment? When looking at collision avoidance, for example, we need to focus on the micro spatial scale. Even after 25 years, post-construction fatality monitoring is a somewhat “blunt” instrument; moreover, looking for dead birds or bats after the fact does not tell us much about the timing or specific circumstances of collision events. Collision detection technology could improve our risk modeling ability for land-based wind projects, and is absolutely essential for both monitoring and modeling what is happening at offshore wind energy turbines.

There is a lot involved in developing a sensor. Key considerations include:

- *Biological Relevance* - Getting the spatial scale right is critical; likewise what assumptions can you use to make inferences from what you’re measuring (collisions) to the biological impact. We need to know where in the species’ life frame that collision occurs, how many samples we can expect to get, and how individual incidents scale up to population impact? We can model but may not be able to measure the probability of a collision.
- *Statistical* – Knowing whether something occurs is very different from knowing the rate at which it occurs. How will the data be analyzed, and how much error is acceptable? What trade-offs can be made in terms of cost? How should the technology be deployed; if the goal is to model

impact, we would want a representative sample of turbines, whereas if the technology is being deployed as part of a management system (detection/curtailment), we would likely use different turbines within the array.

- *Engineering and Logistics* – There are a number of considerations just in terms of installing and getting data from sensors. How (and how much) power can the sensor draw? How to access the data the sensor is collecting? There may be physical space limitations. In the marine environment, technology needs to be water- and salt-tolerant. Adding extra equipment to turbines could affect operations and maintenance. Ideally some of the capacity to add sensors has to be built into the turbine structures; in any case, it is important to plan well ahead rather than try to retrofit existing structures.
- *Testing and Transparency* – Testing and repeated validation is an essential part of developing any technology, and it is essential to be as transparent as possible about testing and validation results with the biologists and statisticians who will be analyzing the sensor data and with the regulators who will make use of their analysis. (Example: WEST working with TNO and NREL to move the WT-Bird system from lab testing to testing and development of a machine-learning algorithm on an NREL turbine, to field testing with a commercial land-based turbine, and eventually to full validation on a commercial offshore turbine.)

  In particular we are interested in the detection rate: what are the chances of the sensor detecting an 8 gm (or 25 gm) bird or bat? In addition to the base detection rate, we have to report the *a priori* false positive and false negative rates. These are critical numbers to report, so biologists and statisticians know what to make of the data. In the case of WT-Bird, we are using a second technology – a camera – to cut down on the number of false positives and negatives.

Trevor Peterson – Bats and Offshore Wind

Most of what we know about offshore bat activity is based on acoustic monitoring, with sensors mounted on lighthouses, buoys and other structures. We know that bats are widespread offshore, but only during limited times of year and limited conditions. This is analogous to the seasonal nature of bat impacts we see at terrestrial wind turbines. The question of whether bats are attracted to turbines (and if so, at what scale) is of special interest for offshore wind development; in the absence of trees or other structures, the presence of turbines could potentially change bat behavior in this space. If bats are present and turbines are on, there is risk of collision, but what is the magnitude of that risk offshore?

Offshore bat occurrence has been monitored in three different regions: Great Lakes, the Gulf of Maine, and the mid-Atlantic. As we have seen onshore, offshore bat activity is seasonally predictable, consistently peaking from late summer (mid-August) to early fall (mid-September).

Based on what we have seen, we cannot avoid bats through siting. All the potential areas on the U.S. East Coast have similar risk profiles in terms of seasonal bat presence, for the most part during warm, calm conditions, primarily of long-distance migrants such as Eastern red and silver-haired bats. The primary impact would be collisions (at the micro-scale), not displacement. Activity occurs during relatively warm, calm weather, which is promising from both a risk and an energy generation perspective.

To learn more about how often and what magnitude of fatalities might occur, we have a limited number of tools. Acoustic sensors show promise, particularly for telling us *when* bat activity occurs. Because wave and wind noise do not interfere with ultrasonic signals, bats are easier to measure acoustically than birds. Thermal/IR video imaging of the type that can work with small birds could also work for bats, but that becomes more complicated to manage technologically.

The first goal is to find out when bats are active in the rotor-swept zone, and here a lot of what we've learned from terrestrial turbines applies. We don't need to reinvent the wheel, just adapt it to the more hostile marine environment. We also have to measure and manage risk without the benefit of empirical fatality estimates, which means we have to do a lot of extrapolation based on monitoring a very small subset of these offshore facilities. So for example, we can make good use of acoustic monitors not to get at the number of bats flying around turbines, but to refine our understanding of *when* bats are present (both dates and time of night) and under what conditions (wind speed, temperature).

At the meso- and macro-scale, it would be useful to know at what scale bats may be attracted to turbines, and possibly changing their flight behaviors. We could try to use nanotags or Very High Frequency (VHF) transmitters to measure activity, but it is difficult to get enough data to draw useful conclusions. So our first focus is on quantifying the amount of time and frequency (as well as under what conditions) bats are flying in risk zones.

Ruben Fijn – "Solving many small puzzles to master the big one…"

Understanding what is happening with birds around offshore wind energy projects requires using different technologies to fill in many different knowledge gaps. To research the impact of anthropogenic activities – particularly offshore wind – on Sandwich terns in the North Sea, we use both visual and aerial surveys to determine how many birds are in and around wind farms, what types of birds, what times of year, and are they avoiding turbines on a large scale? We use radar to measure flight intensity (flux, or how many birds are moving through the area) and altitude.

In 2010, we tried monitoring collisions using the WT Bird system, but the technology was not yet effective enough, and we had to rely instead on collision rate models. It is important to know the parameters, but this presented an additional set of puzzles, as we needed to learn more to get those parameters. We also started building displacement models.

Individual bird (GPS) tracking helps us fill in some of the missing parameters we need for modeling, allowing us to learn about distribution of the animals, and also about various aspects of flight behavior (e.g., flying at rotor height). Tracking allows us to build individual-based models and quantify additional mortality due to displacement. For this we developed matrix population models for various species, and this in turn allows us to assess cumulative effects of multiple wind farms and bird populations in Western Europe.

See the following on-demand presentations for results of Bureau Waardenburg's offshore work:

- #30: Estimating cumulative numbers of collision victims, and impact assessment on population level
- #39: Predicting annual variation at large spatial scales in at-sea foraging distribution of a mobile seabird of high conservation value
- #62: Ecology of scour protection in offshore wind farms – biodiversity enhancement, ecosystem-services and options for eco-design from Europe
- #67: Automated measurements of bird movements in an offshore wind farm

Audience Questions & Panelist Response/Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- Pre-construction surveys and risk assessment
- Post-construction monitoring and risk management
- Logistical challenges for offshore technology

Pre-construction surveys and risk assessment. *Panelists responded to questions about where bats have been detected offshore; and types of pre-construction risk assessment methods being used.*

Where have bats been detected offshore? The expectation is that we would find bat activity in most offshore locations. On the Great Lakes, monitored bat activity is similar to that seen off the East Coast, with the addition of some spring migratory behavior. There has not been concerted monitoring along the Pacific, except for some studies near San Francisco. The U.S. Geological Survey (USGS) is initiating acoustic surveys for bats off the California coast. We would expect to see a different suite of species on the West Coast. There has been a lot of acoustic work in the North Sea; here too, most bat activity is seasonally predictable. Using VHF tags to learn more about their offshore activity, researchers have regularly encountered both a migratory species and a mostly mainland bat that also forages offshore.

What technologies are used for pre-construction risk assessment offshore? Because birds and bats are found basically everywhere – on and offshore – we can't just avoid impacts through siting. To manage risks we need to focus on figuring out which species are present and when.

- Radar can be helpful for tracking movement including flight height, which is important for assessing risk. It is not useful for identifying species, and it is challenging to make use of radar before there are structures in place to mount the equipment.
- For bats, buoys can be used to mount acoustic monitoring equipment to measure smaller-scale activity patterns.
- GPS tracking can fill in some knowledge gaps about where individual animals go, where they are spending time.
- There has been a concerted effort to collect regional offshore data using high-definition aerial surveys.

Because the offshore environment is much more dynamic, pre-construction monitoring needs to take place over a longer period. Also, we are starting with less previous knowledge than we when considering onshore wind energy sites.

In the Netherlands, monitoring started on a very small scale, but variability was so high that it was not very informative, and so there has been a shift over the past five years toward monitoring on a larger scale. Once you know what's there (on a larger scale), and by taking into account radar data from existing sites, then you can start building risk models. The difficulty is that individual wind developers do not want to do large-scale monitoring – government support is needed to fund and coordinate larger-scale monitoring and research.

Could existing fishing and shipping vessels be used to gather information about large-scale bird and bat movements? Certainly they could, but it is a question of what such "opportunistic" data mean from a research perspective, particularly if the presence of vessels affects animal behavior. Some species of birds, for example, are attracted to vessels (especially to fishing boats), whereas other species' activity is disturbed by vessels. Bats are less interested in boats, so this may be more useful for gathering pre-construction information about bats. (Post-construction, it is fairly easy to deploy acoustic detectors on turbines, which is not the case for radar.)

Post-construction monitoring and risk management. *Panelists responded to questions about what options are used to conduct post-construction monitoring; camera and sensor capabilities; and how radar detection is used to inform curtailment.*

What technologies are used for post-construction or impact monitoring? Once a wind energy facility is operational you have structures on which to mount technology. (See below for some of the deployment challenges.) For example, radar can be used to detect movement in the vicinity of wind projects, including direction and speed targets are traveling, and also flight altitude. For actually measuring collision impacts, we cannot look for carcasses after the fact, so need to use a combination of sensors and cameras to detect collisions.

In the case of both pre- and post-construction monitoring, we have to watch out for bias inherent in information gathered during calm conditions; the risk to many animals may be higher during harsh conditions, and what we learn about where animals are and what they are doing during good weather may not inform us about the risks they face during inclement weather.

Are cameras or sensors capable of detecting small birds or bats? The speed of a turbine blade is very different at the tip vs. at the hub. To detect small bats and birds (7-8 grams), we need to put sensors near the blade tips. The idea would be to use the sensor to detect the collision, and a camera system (which could be mounted at the hub or nacelle) to figure out what kind of animal it was.

What is trigger with radar for turbine shut-down and how long does it take? Onshore, radar has been used to trigger shutdowns, but typically only for certain species of concern, such as migrating raptors. We need some way to ground-truth what it is we're picking up with the radar, so that we don't shut down turbines for common species, but only species of concern. On land this might be with human observers or cameras; offshore it would have to be some sort of camera technology. Have to carefully choose the right type of radar application if using that for curtailment.

Reuben: One of the concerns is migrants from Scandinavia crossing North Sea. Typically they wait for the right conditions – no heavy rain or headwinds (October) to cross, generally at high altitudes. But under unfavorable conditions they can come down to rotor height in large numbers. Those mass migratory events are where the risk of collision goes up. To mitigate those mortality rates, we try to predict when peak migrations are occurring. Couple that with radar to detect birds at rotor-height, and that in turn could trigger curtailment of a turbine or set of turbines or entire wind farm for that night.

Challenges for deploying offshore technologies.

It is extremely difficult to retrofit offshore turbines to install equipment, and harder as well to perform adaptive management. Much more advance planning is therefore critical in the offshore environment.

- Wind turbines are electricity sensitive. Installing radar equipment on a turbine structure can cause problems for the turbine's electrical system. Manufacturers also are leery of mounting technologies using metal materials, because the metal attracts lightning.

- It is very difficult to access offshore turbines, not only to retrofit with monitoring equipment but also to check on or repair that equipment, make adaptations, or even to collect data.
- Big fiber optic cable needed to transport terabytes of data from radar to shore. Getting the data also presents a challenge. There has been a move to get access to SCADA systems if trying to integrate shut-down signals from detection technology.
- Floating platforms present different challenges than stable platforms.

Challenges are not limited to technology installed on turbines. Aerial surveys, for example, generally are conducted at an altitude of 250 feet, but if there are turbines present, aircraft need to fly at a higher altitude. Most of these technologies are at the proof-of-concept stage. Given the challenges involved in deployment, we want to be sure that the concept works and will give us data that is useful – whether for making operational decisions at a particular project or for improving risk assessment models that can be used to inform decisions at multiple sites.

Wind Energy and Wildlife: Grand Challenges and Opportunities

Moderator: Paul Veers – Senior Research Fellow, National Renewable Energy Laboratory

Panelists:

- **Jay Diffendorfer** – Geosciences and Environmental Change Science Center, U.S. Geological Survey
- **Katherine Dykes** – Head of Section, Systems Engineering & Optimization, Denmark Technical University
- **Amanda Hale** – Professor & Graduate Program Director, Biology Department, Texas Christian University
- **Todd Katzner** – Research Wildlife Biologist, Forest & Rangeland Ecosystem Science Center, U.S. Geological Survey
- **Eric Lantz** – Wind Program Analysis Platform Lead, National Renewable Energy Laboratory
- **Jenny McIvor** – VP, Environmental Policy & Chief Environmental Counsel, Berkshire Hathaway Energy

Link to Recording: https://wwrm2020.brand.live/c/live-thursday

This panel, led by Paul Veers, Katherine Dykes, and Eric Lantz, explored the implications of wildlife risk assessment and mitigation to technological innovation in wind energy. Panelists discussed the need for an interdisciplinary, systemic approach involving engineering and biological sciences that can be translated into research and innovative solutions for wind energy development and operation on a scale large enough to meet the climate change challenge.

Moderator Paul Veers set the stage by putting the "Grand Challenge" into historical perspective. Windmills have been an important technology throughout human history, driving grain mills and water pumps. There were over a million windmills in the U.S. Great Plains before rural electrification. In the 1970s and '80s, the major challenges to developing wind energy had to do with the aerodynamics, structural engineering and cost of turbine equipment. As turbine systems were optimized, costs have fallen and larger, more efficient turbines are being installed. We are now looking not so much at how to optimize individual turbines but entire wind plants. Optimization also extends beyond the physics of the wind energy production to the biological and environmental and social issues. This panel is about engaging the full scope.

Katherine Dykes – Wind Energy Systems Engineering & Grand Challenges in Wind Energy (Physical) Science

With increasing electricity consumption worldwide, there is an increased demand for clean energy. Wind now supplies about 5% of global electricity demand (0.6 TW), and is expected to grow to 2-6 TW by 2050. Growth on that order of magnitude requires not just incremental expansion, but a paradigm shift: "A Grand Vision for Wind Energy." In October 2017, the International Energy Agency (IEA)'s Wind Technology Collaboration Programme convened over 70 experts from 15 different countries to explore the Grand Challenges of Wind Energy Science. In an article published in *Science* in October 2019, Veers, Dykes, Lantz, et al. summarized the findings and identified three fundamental physical science challenges to achieve wind's global energy potential:

- **The physics of atmospheric flow**. In terms of atmospheric science, we need to look at large-scale weather phenomena (which are changing as the climate changes) and how they affect air flow at the regional, project and individual turbine level. We used to be able to de-couple these phenomena, but now we have to consider the behavior of a very large system that crosses geospatial and temporal scales, and to consider both how the global system impacts flow down to individual turbines and the impact of turbines on atmospheric air flow.
- **The system dynamics and materials.** Wind turbines are the largest rotating machines on Earth, and while it is in many ways a mature technology, the complex dynamics, control systems, and materials requirements of these massive machines still pose significant engineering challenges.
- **Optimization and control of fleets of wind plants.** How do we integrate fleets of hundreds of individual generators so that wind does not just contribute a supply of electricity but actually supports the electric grid in a reliable and sustainable way?

What is lacking from this picture of the physical challenges is the broader societal perspective: the environment and social sustainability impacts. Systems engineering is an approach that targets complex systems involving many disciplines, many stakeholders, long operational time scales and interactions in which a single component, such as a wind turbine, both impacts and is impacted by larger systems. It allows us to include social science as well as physical engineering considerations in our thinking.

The Levelized Cost of Energy (LCOE) is a formula for comparing technologies with respect to different design objectives. We can bundle different aspects and boil them down to a single metric. Typically we design a system that gives us the lowest possible cost of energy and then treat everything else we haven't accounted for as constraints. In practice, this looks like a model with many variables – location, infrastructure, turbine types, systems design, installation, logistics, etc. – where broader impacts such as noise or flicker, exclusion zones, and sustainability impacts (materials, waste, emissions) are typically treated as constraints.

The question is, how do we go from treating sustainability, social and environmental impacts as "constraints" to bringing these factors into the overall design process? Many of us are advocating for more collaboration across research domains and between the research and industry communities, so that wind and other renewables can become the backbone of a future clean energy system.

Eric Lantz – Grand Challenges in Wind Energy Science: Intersections with Biological Sciences

What does wind energy deployment look like if we're going to meet our carbon goals? Virtually every region has competing wildlife land use challenges. Habitat distribution for wildlife species of interest is ubiquitous. In addition to wildlife – and especially across the eastern half of the United States – siting presents public acceptance and radar considerations.

In 2014, when approximately 65 GW of wind energy supplied 4.9% of U.S. electricity consumption, that wind energy fleet's footprint overlaid on a map of the Continental U.S. shows most of those facilities in a band across the Central plains and upper Midwest. By 2018, wind had expanded to about 98 GW (6.5% of electricity supply), with most of that expansion occurring in the same regions.

If we look at where the wind resource is, where the load is, and the transmission infrastructure needed to connect those two, we can try to envision what those maps might look like in a scenario in which wind provides 22% of our electricity (e.g., 260 GW by 2050), or 39% (500 GW), or as much as 47% (630

GW). These are not predictions, and they do not factor in wildlife or social considerations. What these scenario maps do is help us to grasp the magnitude of the growth we are contemplating, and where there is potential for expansion from a business model perspective. (Note: scenario maps did not include offshore installations.)

The scale of the challenge – going from 5% to 50% - is remarkable. It requires different ways of thinking about the challenge and the research needs. We need to step up the collaborations between systems engineers and ecologists and others, so that we can get to innovative solutions that exist but may not be immediately obvious. The key task is to discern the respective trade-offs of on- and offshore deployments, particularly on the east coast where so much of our energy demand is concentrated.

Questions about Eric's maps:
Does onshore map include greater sage grouse habitat? We did include greater sage grouse in one of the data layers, but didn't specify designated habitat. Purpose of map to show that 98-100% of the continental U.S. overlays with potential wildlife impacts for species we care about. More work is being done on this.

How do you define "footprint" of wind facility? This is yet another area of subjectivity – that's one of the challenges; what really drives the impacts – depends on what kinds of impacts you're looking at. You can make a case that wind has a huge footprint, which is what you see in the scenario maps I presented. But depending on the impacts you're concerned with, you could make the case that the footprint is much smaller because most of the land within a wind plant, between turbines, is available for other uses and is undisturbed.

Panel Discussion

Panelists responded to questions from the moderator and audience, focusing on the following broad themes:

- *What are the top challenges and opportunities?*
- *From an industry perspective, how does past experience inform the challenges we now face?*
- *How should this inform our work in the area of wind-wildlife research and development?*
- *What tools or approaches might be borrowed/adapted from other industries or impact-management situations?*
- *What are the 2-3 big obstacles to achieving the wind energy "grand vision"?*

What are the top challenges and opportunities with respect to wildlife? *Biologists on the panel responded in terms of species of current concern (birds of prey, bats, and habitat-sensitive species) as well as species which may not be on our radar yet.*

For eagles and birds of prey, the biggest challenge is siting. Our understanding of the physics of atmospheric flows informs where we put wind turbines on the landscape, but years of telemetry and other data also informs us where the birds will be. The overarching challenge will be to address the turbine, site, and fleet design challenges while optimizing for wildlife. For eagles and other large animals, we should be able to come up with creative solutions based on our knowledge about populations and use of the landscape and airspace.

For bats, siting is not a solution. Bats are everywhere; we are not going to avoid them. There is increasing evidence of bats being attracted to turbines, and we have huge data sets on how bats interact with turbine structures. The challenge is to get at why bats are attracted, what sensory cues are key, and what we can do to reduce high-risk behaviors.

One challenge is that the migratory bats most impacted do not have protected status in the U.S., so while we have some tools that can reduce risk (e.g., raising cut-in speed), the existing regulatory framework is not conducive to requiring what may be costly strategies from an energy producer's perspective. Finally, given the lag-time for developing these technologies, the challenge is how to ramp up fast enough so that these technologies can be deployed as build-up occurs rather than having to go back and retrofit.

A related but separate challenge is that we have very little understanding of bat populations – again, particularly for the migratory bats. The Structured Decision-Making model (see presentation: Robin Gregory & Philip Halteman – Planning the Future of Wind-Wildlife Research) is very promising, but lacking population size data, how do we know what constitutes an "acceptable take"? That said, we do know that raising cut-in speeds on low-wind nights at certain times of year works. We have to take some action with what we do know now, to buy time for the research to reduce key uncertainties.

For habitat-sensitive species, we need to look at impacts on a broad scale. We've digitized 35-40 wind facilities to look at habitat fragmentation. Companies are trying already to optimize layout to minimize road construction, but there may be room to improve that. One approach would be to see how habitat considerations might constrain NREL's build-out model; and also look at the flip side – i.e., if we do build out as envisioned, how would that impact sage grouse and other habitat-sensitive species.

Keep in mind species not yet on our radar. Given that wind build-out and climate change impacts are going to be occurring simultaneously in the coming decades, there are species on our radar screen now that have been not a concern with respect to wind impacts, because overall populations are stable. But if climate change makes those populations less stable, it may be that the wind fatality impacts start to matter more.

From the industry perspective, how does past experience inform the challenges we now face? *How do we incorporate into the Levelized Cost of Energy those environmental and social impacts that are less easily monetized? How do we deal with uncertain and subjective factors? How do we think about these factors given the long life-cycle of wind turbine projects?*

The challenges have changed. The challenges for wind development have changed over even a short period of time. When we started building wind in Iowa in 2008, the biggest issue was cost and rate-making regulations. Now it's more about permitting. Mid-American spent about five years developing a Habitat Conservation Plan and incidental take permit approach. Generally, the wind industry knows how to work with the permitting process to address risks to listed species, and wants to be part of the environmental solution. And to the point about species "not yet on our radar" – once a species is listed, regulatory requirements become more burdensome, so it is in the industry's interest to anticipate and not push species over that threshold.

Incorporating non-monetized impacts into planning is a hot topic. From an energy markets perspective as well as in terms of sustainability objectives and concerns, there are a number of factors that are not as easily quantified or monetized that wind turbine manufacturers and facility owner/operators have to consider as we design machines, site facilities, and build out systems. We want to continue to deploy wind while making sure that other consequences are minimized, so we need a way to bring these considerations into our decision-making framework. There are always going to be trade-offs between profits and impacts, especially as we think about the whole life cycle of wind energy projects.

Incorporating uncertain and subjective factors is a challenge. Highly uncertain and subjective factors are hard to incorporate into a robust quantitative optimization approach. The time horizon we have to achieve climate solutions is too short to resolve uncertainty. We need an all-hands-on-deck approach to drive down critical areas of uncertainty, but we will have to compromise to service the array of societal objectives. It is a difficult problem, but we need to be open to being more creative. We should not let unknowns hold us back, so we need to work on parallel paths, addressing key uncertainties while rapidly building out to minimize climate impacts.

Projects will be on the landscape for a long time. We build wind projects designed to operate for 30-40 years, and those can be repowered, so projects once built are going to be on the landscape for a long time. What will impacts look like over the life of a wind project? We need to think not just about immediate impacts, but about how to predict the kinds of impacts we'll be needing to manage 20 years from now. Maybe we cannot save a specific species. Or as a result of climate change, we may find other species moving into new areas to adapt.

How might/should this inform the future of wind energy/wind and wildlife research and development?

Incorporate environmental concerns into the development process. On the environmental side, we tend to be in a reactive mode much of the time, measuring impacts and publishing papers about how poorly we predicted those impacts. The systems engineering approach offers an exciting opportunity to start incorporating environmental concerns into the development process, to think about how we integrate solutions into the design. Moreover, we need to think not just about the turbines that are being installed today, but about those being planned for five years from now; we need to be involved in the early project development stages.

We have an opportunity to impact the nature of the technology as it is being deployed. An industrialized carpeting of the landscape with cookie cutter-designed wind farms is not something we want to see, so we need to tailor the technology so that wind energy plants sit lightly on the land.

Embrace uncertainty. There is a temptation to just want the answer, so that we do not have to make continual tweaks over a project's 40-year lifespan. But recognizing that we are not going to solve everything upfront, we need to embrace adaptive management. Everything ecologists do is conditioned on uncertainty – multiple uncertainties – and that may be what we can bring to the research, design, and development discussion: a greater tolerance for working under conditions of uncertainty.

On the engineering side, we can use modeling to address uncertainty in ways that allow us to pose and investigate questions that we couldn't even ask 10 years ago. For example, we can calculate the costs and impacts associated with allowing eagle populations to decline 10% below USFWS guidelines, as compared with the costs and impacts of keeping those populations stable, or enhancing them. In other words, we can bracket uncertainty using different scenarios, and then it is up to the policymakers to decide.

How can we make better use of a wealth of data? A major challenge is figuring out how to share data and translate the research into implementation. The wind industry sits on a wealth of data which could be used to help answer some of the questions about impacts and species populations. But there is risk for companies in sharing their data, so we have to find ways to manage that, and we should also think about ways to make use of the data that are not limited to peer-reviewed articles.

Scientists don't always present our research in ways that are useful to wind developers. We make a lot of assumptions in our research, but if the risk models we develop (for golden eagles migrating through Pennsylvania, for example) do not take account of the way developers are thinking about siting and design, those models are not going to be very useful. Moving forward, we plan to make maps for developers that show where eagles are going to be flying and at what heights. Posting those GIS maps to a website may be a lot more useful than our model. (That said, we may need to educate the funding community; research funders typically are looking to support work that results in published papers, not webpages.)

Could data – or risk – be shared? We can craft agreements around sharing of information about species of concern such as condors or whooping cranes – large animals that are being tracked – to facilitate detection and risk reduction at different wind facilities within a region. It is much more challenging (and less likely) that different companies would be willing to interconnect their SCADA (turbine control systems), however, in part because of cyber security concerns. But there are other ways to share information. We all share similar set of goals and challenges, so there is promise for exploring how we help each other out.

We may be at (or almost at) a point where we could spend less time and money on monitoring that is just telling us more about what we already know, and use those resources in more creative ways to finance conservation. There are many external forces impacting bats, for example. Rather than implementing the same cut-in speed at all wind facilities, a more holistic approach might be to curtail where wind costs are less expensive – or where bat impacts are highest – and then to share the cost of that lost energy production across facilities – or even with other industries and society at large.

Are there tools or approaches might be borrowed/adapted from other industries or impact-management situations? *Panelists spoke to the value of having more interdisciplinary discussions, noting examples from the fishing industry, noise regulations, sustainability ratings, and approaches to quantifying the value of biological resources.*

Bi-catch in the fishing industry. There is a mature governance framework around "bi-catch" in the fishing industry – e.g., dolphin getting caught in tuna nets. There may be parallels for the wind industry – turbines are intended to "catch" wind energy but incidentally collide with bats or birds. It might be useful to look at how commercial fishery regulations allow fisheries to operate while protecting marine mammals.

Noise and flicker regulations. It is cheaper to make and deploy noisier machines, but noise has negative impacts, and in response to regulations manufacturers have come up with design solutions that address the problem. There may be some design solutions for wildlife (e.g., replacing latticed tower designs with monopoles to eliminate perching opportunities). The main difference is that both the problem and the regulatory structures to deal with noise (and flicker) are more localized than for wildlife impacts.

Sustainability rating tools. To date there has been no industry-wide effort to establish a sustainability rating system. "Sustainability" can mean different things, so while individual companies may be looking at their own sustainability metrics, it might be difficult to apply a single screening tool or rating across the industry. But many companies are having these conversations (about how to assess the full suite of impacts and benefits) internally, and there is widespread recognition that this is an important topic. In Europe, there is some consensus that the industry would benefit from a standard set of approaches to assessing sustainability to facilitate discussion among stakeholders. Other energy technologies would benefit as well, as would policy makers.

A 2019 literature review of 179 published papers came up with over a thousand unique environmental metrics for comparing impacts across energy sources. A lot of work is needed to achieve standardization.

Is it possible to calculate negative externalities of energy and factor them in as business costs? There is a very large field of study in conservation biology on how to value biological diversity and biological resources. For example, economists have looked at the crop pest control value contributed by free-tailed bats. And even the social value of monarch butterflies has been monetized based on what people are willing to pay to plant milkweed to sustain them. Value judgments are inherent in this, but this is a well-developed area, and there are people we could bring to the table who could contribute to this discussion.

What are the 2-3 big obstacles to achieving the wind energy "grand vision"?

Where can we produce energy and get it to market? Permitting – not only for wind facilities but for transmission – is a lengthy process, especially on Federal land. (We cannot avoid building on Federal land and achieve the kind of build-out that will impact climate change.) Local opposition ("NIMBY") to any kind of infrastructure also could be an impediment. Twenty years ago, it was all about making a commercial business case; now it is more about having space available to develop.

Thinking about this from a global perspective. From a more global perspective, it's about getting wind and renewables EVERYWHERE. The physical challenges of wind installations and operations are different in different locations, and the environmental and other impacts in any given spot on the globe are different.

Lack of public consensus about climate change. In the U.S., at least, there is still a lot of denial and lack of urgency about climate change. People do not see that a 2-degree C world is scary and a 4-degree C world is disastrous. That said, even if we agree that the impacts of climate change are worse than the impacts of wind turbines, if we were to achieve the maximum build-out scenario without coming up with more wind-wildlife solutions, we will eliminate some number of species.

That's why we are here, to get people in the same room to understand broader issues and think together about the trade-offs.

Additional Resources:

- Grand Challenges Webinar (June 2020)
- NREL News Release
- Journal Article
- Article Response E-Letter

Eagle Behavior and Wind Energy Siting and Operations

Moderator: Stu S. Webster – Senior Manager, Technology Innovation and Research, American Wind Wildlife Institute

Panelists:

- **Peter Bloom** – Zoologist, Bloom Biological, Inc.
- **Robert Fisher** – Supervisory Research Biologist, U.S. Geological Survey
- **Tricia Miller** – Senior Research Wildlife Biologist, Conservation Science Global, Inc.
- **Eliot Quon** – Wind Energy Research Engineer, National Renewable Energy Laboratory

Link to Recording: https://wwrm2020.brand.live/c/live-friday

This session began with an NREL presentation on a project to combine knowledge of eagle behavior, eagle telemetry data, atmospheric and wind power plant flow models, and machine learning to develop tools that predict eagle behavior and risk around wind power plants. The discussion focused on:

- How a clearer picture of the atmospheric flow dynamics of wind energy generation, along with ecologists' understanding of eagle behavior, can help us make useful predictions about Eagles' use of airspace around wind facilities
- What we know about eagles' use of landscapes and airspace on the regional- vs. facility-scale: including avoidance, territories, nest site fidelity, and life-cycle behavior
- The impact of wind energy facilities on local landscapes and atmospheric flow

Eliot Quon – Atmospheric Modeling to Enable Prediction of Golden Eagle Interactions with Wind Power Plants

See also on-demand presentation #94: High-Fidelity Modeling of Eagle Soaring Habitats Near Wind Plants in Complex Terrain.

We use computational fluid dynamics in the design of wind farms, and the same type of modeling can help us understand the flight environment from an eagle's perspective. A video example illustrates how such models are used to calculate the maximum number and optimal distancing of turbines within an array, given that each turbine impacts both kinetic energy and turbulence downstream. In the video example, we can see that the wind speed is approximately 9-12 m/s between the turbine rows and around the array, but that wind speed is much lower (3-6 m/s) and more turbulent along each row of turbines.

The U.S. Department of Energy Wind Energy Technologies Office has funded the development of two models:

1. Mesoscale model characterizes soaring habitat across the contiguous U.S. using atmospheric modeling methods and knowledge of golden eagle flight dynamics; and
2. Microscale model that can be used to predict eagle behavior and risk. The latter (comprising 75% of the effort) uses high-fidelity wind flow models, machine-learning methods, and eagle telemetry data to predict eagle flight trajectories at the wind power plant-scale.

For the mesoscale model, the project team is creating a “hindcast” applying improved physics air flow models to publically available wind data from the past 20 years to produce a flow map for the continental U.S. with 2-km spatial and 5-minute temporal resolution. The model can be used to improve simulations of air flow within as well as around wind plants, and detailed terrain maps and thermal updraft parameters allow us to add a vertical velocity layer. This information is combined with what we know about the physics of eagle flight – e.g., the updraft velocity needed to sustain soaring – to produce a GIS layer of soaring habitat across the continental U.S. Results will be disseminated through the National Renewable Energy Laboratory (NREL) Wind Integration National Dataset (WIND) Toolkit. (See on-demand presentation #*102: Development of a meteorological data set to support research of volant species*.)

The microscale project applies high-fidelity, turbulence-resolving flow models along with telemetry data and knowledge of eagle behavior to train a machine learning model. High-fidelity flow modeling involves running simulations with high-performance computing, sometimes for days or weeks at a time. We are able to run multiscale simulations that couple mesoscale weather models with microscale large-eddy simulation to realistically represent turbulent atmospheric flow over regions in complex terrain of unprecedented size. (See on-demand presentation #94: *High-Fidelity Modeling of Eagle Soaring Habitats Near Wind Plants in Complex Terrain*.) The combined result will be an open-source eagle behavior and presence-modeling tool that can accurately account for atmospheric flows and terrain, help site wind turbines within power plants to minimize risk to golden eagles, identify conditions associated with high probability of eagle presence and risk, optimize investments in impact minimization technologies, and help develop golden eagle mitigation strategies. (See on-demand presentation #*102: Development of a meteorological data set to support research of volant species*.)

Detailed microscale turbulence simulations can allow us to map the flow field within a wind facility, including the vertical velocity fields created by orographic and thermal updrafts. So for example we can see how the flow field is characterized by small-scale patches of turbulence at the atmospheric boundary layer during early morning and late afternoon, with primarily orographic updrafts dominated by terrain features. As thermal updrafts predominate during the middle of the day, we can see unstable convective cells forming, creating an environment conducive to eagle soaring behavior.

The goal is to translate all these model results into something the wind-wildlife community can readily access: a generalized model that can be applied to a variety of different sites, yielding high-resolution (50 m) probability maps of eagle presence on a given terrain. Real-world observational data can then be used to calibrate the model parameters and validate the outputs.

The summarized eagle presence map incorporates several dimensions of uncertainty, including: spatiotemporal uncertainty in wind conditions, uncertainty in eagle decision making, and uncertainty in how eagles might approach a particular wind plant. This gives us a probabilistic map of presence without requiring prohibitive data collection. (See on-demand presentation #111: *Quantifying Turbine-Level Risk to Golden Eagles Using a High-Fidelity Updraft Model and a Stochastic Behavioral Model*.)

Panel Discussion

The panel discussion revolved around the following questions/topics:

- What is the latest science/modeling telling us about eagle use of air space within wind farms; how predictable is eagle behavior?
- What do we know about how eagle territories and their use of the larger landscape?

- How does the presence of wind farms impact the landscape and the airscape?

What is the latest science/modeling telling us about eagle use of air space within wind farms? *How predictable is eagle behavior?*

A lot of factors come into play when characterizing the eagle flight environment. For example (as indicated in on-demand presentation #*94: High-Fidelity Modeling of Eagle Soaring Habitats Near Wind Plants in Complex Terrain*) the effect of orographic lift decreases with height at about 90 m. This transition zone is proximate to the rotor swept area, so may impact risk. What is happening locally in the atmosphere can be driven by what is happening farther away. Here there is room for a more detailed investigation at a smaller scale, perhaps using radio-tagged eagles to learn how eagles actually use this transition space between 90 and 100 m.

There have been many modeling efforts to date on eagle flight behavior, but previous models have used single GPS position points and assumed that each point has equal risk without knowing what behavior the eagle is actually engaged in at that point. We're now able to move forward as we understand what behaviors eagles are engaged in when we see them at different points. See Silas Bergen's work modeling bald eagle behavior in Iowa (on-demand presentation #47: *Improved behavioral classification of flight behavior informs risk modeling of bald eagles at wind facilities in Iowa*) from high-resolution telemetry data. At the same point in space, a bird engaged in straight flight is likely at less risk than a bird that's circling.

While there may be more regionally-specific factors affecting eagle behavior in different locations, the interaction between air flow and flight dynamics should apply regardless, because the physics are the same.

What do we know about how eagle territories and their use of the larger landscape?

Robert: From a landscape perspective, eagles have a fairly constrained landscape from Los Angeles to northern Baja Mexico. We have a lot of movement data showing us how eagles use the landscape in relation to human uses and the edges between human activity and less developed or populated landscapes. Resident eagles tend to be avoiding the wind development areas. So we have to think about making sure we do not create a map that eliminates air space for eagles. Eagles have multiple sources of fatality, and we may be coming to a tipping point in Southern California.

On a continental scale, eagles coming from Alaska are not moving down to California; they are migrating to the northern Rocky Mountains. So wind resources in California are not impacting that population of golden eagles.

What do we know about nest territory fidelity, and what bearing does that have on siting?
Around northern Kern County, California, eagle populations have declined and are continuing to decline, and it is not clear why that habitat is being abandoned. Eagles tend to return to their natal area, and tend to show site fidelity as adults. Eagles range quite far, so they may be recovered far from their breeding territory, but that doesn't mean that they don't return to nest where they fledged. In California, we see tight communities that are faithful to their fledging areas. We also see multiple eagles from different territories congregating at times in the same area. We see eagles from territories much

farther away that are showing up as nomads in disturbed areas that local populations do not use. These are areas that seem to be good eagle habitat, but resident eagles have abandoned it, likely because of anthropogenic avoidance (e.g., rock climbers).

For a point of comparison, there is work being done to look at Chesapeake Bay bald eagle nest area fidelity.[1] We see juvenile bald eagles migrating from their natal areas and dispersing north, then coming back and repeating that behavior. At some point we expect them to stop and settle on a breeding territory, but we have only 3-4 years of data so far, so it is too early to draw conclusions. USFWS researchers have documented similar behavior for golden eagles in the southwest. These juveniles may be at higher risk during this period.

What do we know about how eagles habituate to changes in their environment (e.g., construction of a wind site)? Having followed about 50 individual eagles for 5 years we have seen some birds fly over same mountain range every day to forage, or to a watering hole. Eagles are very habitual, dependable in their daily movements. They do not necessarily react to a new feature in the landscape where those movements are occurring, but they do avoid human activity, so construction (or other human activity at a wind farm) may lead eagles to change their use of the landscape. We have seen a lot of golden eagle territories disappear over time as a result of 50 years of residential development across Southern California. No one change on the landscape puts an eagle territory out of business, but the combination of habitat loss and random mortality events occur, and those eagles are not being replaced. We do not have a clear picture of where the tipping point is.

Can we prudently extrapolate from golden eagle behaviors in So California to other eagle territories? There probably are some behavioral aspects that translate from one place to another. But these have to be considered in the context of regional landscape use differences. We cannot extrapolate from Southern California to Wyoming or Oregon; the prey bases are different. In terms of mortality, we do not see golden eagles getting electrocuted in the East, because they use forest, and there are plenty of trees for them to perch in. (Bald eagles on the other hand, like to perch on power poles even where there are trees available.)

What does regional scale eagle behavior tell us about facility-scale risk?
Eagles have very large ranges. We might have multiple wind energy facilities that resident birds from Palm Springs to Northern Mexico are using as a single territory. We also are trying to understand how landscape and habitat – such as the Appalachian ridge and valleys region – are being used. Development of those ridges could fragment eagle habitat and result in mortality, so ridge tops in the east are not good places to develop wind farms. We need to get a broad idea of what sorts of habitat eagles select in different parts of the country.

How does the presence of wind farms impact the landscape and the airscape?

Noting the striking difference shown in the video between more stable flow between turbine rows vs. more turbulent air between turbines in each row, panelists articulated questions about what this might mean for eagle risk within a windfarm. Does it make a difference from which direction eagles enter the

[1] Miller et al. 2019. Bald Eagles and Bird Aircraft Strike Hazard, The Journal of Wildlife Management, 83(4):879-892.

wind farm? How does the removal of energy from the atmosphere influence eagle behavior? Does wake turbulence lead to predictable reduction of updrafts?

On the latter question, Eliot Quon noted that wake turbulence brings down more energetic flow from above, but because thermal updrafts are strongly driven by solar radiation, the impact from wind farm wakes is probably secondary. (On the temporal and spatial modeling of risk, see on-demand presentation #35: *Temporal, topographic, and meteorological correlates of Golden Eagle flight behavior in California's Tehachapi Wind Resource Area*.)

Another impact of wind energy facilities that may affect eagle use is whether wind farms have a desertification effect, which may in turn affecting prey availability. In very dry areas where wind farms have been operating for a long time, there is a lot more dead creosote than occurs in newly developed dry area wind farms. Eliot Quon noted that desertification is actually an observed phenomenon. The presence of wind turbines does change microclimate around the turbines by a measurable amount (a fraction of a degree, per the Crop Wind Energy Experiment, "CWEX").

One other effect of note is a regional wake-effect. Almost 90% of new wind farms will be impacted by being under some conditions in the wake of existing wind farms. They really are removing energy from the landscape. The tools described in the presentation do give us a way to understand how birds interact with all these wakes.

Novel Approaches to Risk Assessment and Mitigation of Habitat-Based Impacts of Wind Energy

Moderator: John Lloyd – Associate Director of Research, American Wind Wildlife Institute

Panelists:

- **Zara Dowling** – James A Walker Future of Wind Fellow, American Wind Wildlife Institute
- **Matt Holloran** – Owner & Lead Ecologist, Operational Conservation, LLC
- **Chad LeBeau** – Research Biologist, Western EcoSystems Technology, Inc.
- **Jill Shaffer** – Ecologist, U.S. Geological Survey – Northern Prairie Wildlife Research Center

Link to Recording: https://wwrm2020.brand.live/c/live-friday

Most build-out scenarios for wind include extensive development in regions that provide habitat for wildlife of high conservation concern such as prairie-chickens, sage-grouse, pronghorn, breeding ducks, and other grassland-nesting birds. Mitigating habitat impacts may be the most challenging and important topic in wind-wildlife interactions. It involves an incredibly complicated web of systems, and while not as obvious as wildlife colliding with turbines, habitat impacts may be more ubiquitous. How we choose to manage these impacts may influence the pace and geography of wind energy build-out. We do not have the luxury of eliminating uncertainty, so we have to learn as we go, incorporating risk assessment and mitigation in the development process.

This panel focused on grasslands and shrub-steppe ecosystems of the central and western U.S., an area that will be important for wind build-out, and also supports many habitat-sensitive species: sage-grouse, prairie-chickens, pronghorn, even beetles and other insects. Panelists presented on:

- A framework for evaluating the cumulative impacts of wind energy build-out in the context of climate change, identifying critical areas of uncertainty, and prioritizing research
- Effects of energy development on prairie grouse
- A real-world application of risk assessment and habitat impact mitigation

Zara Dowling – Developing a Framework to Evaluate Potential Cumulative Impacts of Land-Based Wind Energy

A survey of state wildlife agency staff by the American Federation of Wildlife Agencies (AFWA) identified cumulative impacts as an important risk that is poorly addressed in current scientific research. Most cumulative impact analyses are done on a project-by-project basis; the results are sometimes inconsistent and likely inadequate to address the true extent or magnitude of cumulative impacts. One reason why cumulative-impact analyses are challenging and rarely conducted is that they can be exceedingly complicated, with many parameters to consider and a scope that can get quite large quite quickly. To address this problem, we created an analytical framework to evaluate cumulative impacts of land-based wind energy development that would be both comprehensive and practicable to use. The framework was constructed around seven primary inputs:

- *Species or species group of interest.* To demonstrate the framework, we chose five example species for analysis that represented a range of life histories and conservation concerns, including a raptor, a migratory tree bat, a habitat-sensitive species, a grassland-nesting songbird, and a Neotropical migrant.

- *Baseline conservation goal*. For this analysis, we used existing management goals, or where none was available, the current population size or extent of area occupied by the species.
- *Direct and indirect impacts.* For each species, we elucidated all potential impacts of wind energy development.
- *Geography of interest.* We focused on wind energy impacts across the North American range of each species.
- *Timeline.* We aligned our analysis with wind-energy build-out scenarios through 2050.
- *Other anthropogenic impacts.* We qualitatively considered other potential impacts of human activity, including climate change; this step can be further refined depending on data availability and interest of the analyst.
- *Future land-based wind scenarios.* We used two different scenarios for wind energy development scenarios of build-out: the DOE Wind Vision and the Stanford Solutions project. The latter provides a maximal build-out scenario in which all electricity needs are served by renewables, including 1500% current wind generating capacity by 2050.

Having identified potential species and habitats at risk, we reviewed the literature to identify the remaining input parameters. The value of this approach is that it allows for a rapid assessment and characterization of potential impacts, including which are likely significant enough to warrant further analysis, which are likely to prove unimportant, and which are too uncertain to ignore. We can focus on avoidance and minimization priorities for major impacts; for those impacts with high uncertainty about the magnitude or probability of occurrence, we can prioritize research that will better inform us about the effects on focal species and mitigation options. Finally, putting wind development impacts in context relative to other stressors on these populations is useful because it provides insight into what other stressors we might reduce to compensate for the expected impacts of wind; in other words, it may help us understand how we could “make room” for wind energy on the landscape.

For this example, we analyzed potential outcomes for the ferruginous hawk. This species is not federally listed in the U.S. but is identified as a conservation priority in 14 states and is listed as a species of special concern in Canada and Mexico. Historically in decline due to habitat loss as grassland has given way to agriculture, populations may be increasing modestly or at least have stabilized in recent years. For this analysis, our baseline goal is to avoid further declines in population size or extent of area occupied.

Based on the literature, ferruginous hawks are sensitive to human presence as a disturbance, particularly during the nesting season, and especially during incubation. Disturbance might be minimized by creating buffers around nesting sites and scheduling construction outside of the breeding season. Delaying maintenance activities in proximity to nests during the breeding season could also be of great benefit. Habitat loss and fragmentation due to conversion of natural habitat and transmission infrastructure appears to be a lower priority for investigation. More significant uncertainties exist around the long-term response to turbines’ presence on the landscape, and whether hawks might begin to display avoidance over the long-term in nest site choice. Additional studies on fledgling survival could also be beneficial.

In terms of collision risk, extrapolating from existing fatality estimates, our estimates suggest that under the Stanford scenario fatalities would represent less than 5% of population being killed per year, and closer to 1% under the DOE scenario. This suggests relatively low risk of population impacts under a modest build-out scenario, but greater risk under an aggressive strategy to deploy new wind energy.

Collision fatalities under the Stanford scenario would likely require some form of compensatory mitigation, with construction of Artificial Nesting Platforms as one potential strategy.

Matt Holloran – Implementing a proactive, adaptive approach to risk assessment and mitigation of habitat-based impacts of wind energy: conceptual foundations

We have about 20 years of research on sage grouse response to energy development in the eastern portions of its range. The concepts presented here are not new, but a slight shift in how we think about these issues could result in broader shift in how we think about development and management of wind energy. This presentation focuses on science-based management, community-based conservation, and compensatory mitigation.

Science-based ("adaptive") management. A 2006 Strategic Habitat Conservation Report from USFWS and USGS presented a structural "Adapt and Iterate" framework to maximize the effectiveness of management over time. Management decisions are made, outcomes evaluated, and these evaluations inform planning and tweaks to management. Examples of programs fully implementing this framework are few and far between; it is not that we don't have an approach to integrating science and management, but we need better implementation strategies.

In particular, we tend to focus on making management and policy decisions based on the data available to us ("best available science") when the decision is made. We may acknowledge that more research would allow us to make a better-informed decision, but default to the position that it may not be practical to wait. This misses the fundamental premise of science-based management, which is that these decisions are not meant to be end-points, but hypotheses to be further tested. In practice, we need more emphasis on the inventory and monitoring research step of the cycle. This is where we test our management hypotheses, and gather the data needed to adapt our management approach based on what we've learned.

As we enter a time when we can expect changing conditions to dictate continuous management responses, we need to focus more on *how* management decisions are made than on *what* those decisions are. In practice, this requires a fundamental shift in the way we "do" science and management. This shift could be accomplished by directly integrating data collection and continual analysis in the day-to-day workings of program itself, rather than relying solely on outside research. What we tend to do now is "management based on science" rather than science-based management. The latter requires making data collection and iterative analyses an integral part of management's decision-making process.

> *The human economy must operate as a good neighbor in both the natural and the human communities, because in the long run the health of one is the health of the other. We humans are never going to understand perfectly the nature of any place, or fit our economies perfectly into local ecosystems. But the right instructions, or the right "model," for our use of a place can come only from the nature of the place."*
>
> *- Wendell Berry*

Shifting the emphasis towards monitoring and making the "adapt and iterate" cycle more integral to how we manage resources allows us to shift from broad generalized policies reliant on stipulations to a management framework more reliant on procedural principles. In many rural communities, local industry tends to play an outsized role in the local economy. Industry could use its influence to engage at the community level with the goal of strengthening local communities. As Wendell Berry points out, the need to hold the local ecosystem together and the need to hold the local economy and human community together are interdependent. The shift from managing local management decisions based on generalized policies to having site-specific monitoring data and analysis inform local decisions would more seamlessly fit into this vision.

Landscape-scale management is critical for the conservation of natural resources, but most of the management done to conserve or restore resources is done at local scales. Stitching these local efforts together in a meaningful way that results in a functioning landscape requires coordination; site-specific decisions must be informed by an understanding of those decisions' consequences (positive and negative) at larger spatial scales.

This places a greater emphasis on industries' role in environmental management and conservation. Renewable energy industries are uniquely positioned to shift at least a little bit from the current paradigm. Compensatory mitigation is going to be more important as build-out occurs. In the mitigation hierarchy, compensatory measures are a "backstop" used to offset residual impacts after avoidance and minimization measures have been taken, and it differs fundamentally from earlier steps in the hierarchy in that it focuses on offsetting impacts to habitat quantity by making improvements to habitat *quality*.

The majority of mitigation measures have a preservation focus, emphasizing set-asides and restricting actions that lead to habitat loss. Yet habitat degradation is an important factor in many species' decline, and compensatory mitigation needs to go beyond set-asides and address the need for habitat restoration. This should not fall only on industry, but industry, scientists, and the agencies all have a role to play. Examples of this include the Cheat Grass Management Task Force in Teton County, Wyoming, and an effort in NE Wyoming to manage invasive annual grasses and restore sagebrush habitat in a holistic way through joint efforts of industry, the University of Wyoming, state government, and nonprofit conservation organizations.

The future is ours to make. The next presentation (Chad LeBeau) will provide some real-world context to these concepts.

Chad LeBeau – Science-Based Framework for Managing Wind Energy Development in Grouse Habitats

This presentation lays the foundation for a framework that could be implemented immediately, to directly integrate data collection and analysis into managing wind energy development decisions in prairie grouse habitats. A key component of this framework is the development of siting tools based on best available science. There are many tools to help with planning wind projects, but a one-size fits all approach does is not sufficient, and these tools would be tailored to managing the impact of wind development on affected grouse populations: helping us evaluate impacts and informing mitigation measures. These tools at the landscape and site-specific scales will be continually updated, so adaptive management is a key component to the success of this framework.

What do these tools look like? With limited data, we evaluate projects on case-by-case basis, and as grouse are a landscape scale species, we need to evaluate impacts associated with facilities at the site level and also on the landscape scale. Understanding how grouse are using the landscape can help us avoid siting a project in an area of critical habitat. At the same time, a project that impacts one aspect of the species' life-cycle (nesting, for example) is going to have impacts on the population across the larger landscape. As we look at how project siting will affect habitat use, connectivity and survival, what we ultimately want to know is, how do these effects impact population stability?

We scientists put managers and policy-makers in a difficult spot when we present studies with varying or conflicting results. The problem is not with the studies, but with the failure to communicate study results collectively in a way that is helpful for practical decision-making. For example, if we report that a project has no impact on female survival but also that it is displacing grouse from suitable habitat, what are the resource management implications? More effective use could be made of this research if we had a way to translate the various impact metrics (nest survival, adult survival, nest site selection, home range, lek attendance etc.) into a meaningful single metric: e.g., population growth rate.

Absent population growth metrics, we can do meta-analysis, but without the population dynamics context for a particular study area, it may not be useful. We cannot wait to fill all the gaps in our knowledge to make management decisions, but we need to be continuously thinking about what else we need to know, how to fill those knowledge gaps, and how to feed that knowledge back into our siting tools as we cycle through the "adapt and iterate" framework.

Jill Shaffer – Tools for the Mitigation of Habitat-Based Impacts

The Northern Prairie Wildlife Research Center and U.S. Fish and Wildlife Service have been studying the impacts of wind energy development on waterfowl and grassland birds in North Dakota and South Dakota since 2003. We do see displacement in both groups of birds. This presentation describes tools that have been developed to complement the avian-impact offset method (AIOM). Because the AIOM itself was presented at the 2018 WWRM in St. Paul and is described in a 2019 Ecological Applications paper,[2] it will not be discussed in detail here. Briefly, the AIOM is a formula that determines the displacement impact of anthropogenic disturbances on grassland bird and waterfowl pairs by calculating the number of hectares of grasslands and wetlands that would be necessary to support the displaced pairs.

The AIOM was developed based on the results of two foundational studies investigating the displacement impact of wind energy projects on grassland birds[3] and waterfowl.[4] As reported in the 2019 Ecological Applications paper, the average displacement (five years post-construction) for eight grassland bird species was 53%, whereas average displacement for five species of dabbling ducks was 18%.

There are four tools available to support the AIOM:

(1) The AIOM formula itself, including the five metrics used to populate the formula, is described in the 2019 paper.

---

[2] Shaffer, J.A., C.R. Loesch, and D.A. Buhl. 2019. Estimating offsets for avian displacement effects of anthropogenic impacts. Ecological Applications 29(8):e01983. 10.1002/eap.1983.
[3] Shaffer, J.A., and Buhl, D.A., 2016, Effects of wind-energy facilities on breeding grassland bird distributions: Conservation Biology 30(1):59–71. https://dx.doi.org/10.1111/cobi.12569.
[4] Loesch, C.R., J.A. Walker, R.E. Reynolds, J.S. Gleason, N.D. Niemuth, S.E. Stephens, and M.A. Erickson. 2013. Effect of wind energy development on breeding duck densities in the Prairie Pothole Region. Journal of Wildlife Management 77(3):587–598.

(2) A series of four PowerPoint tutorials is available from jshaffer@usgs.gov:

- The first provides background on the Prairie Pothole Region and reviews status and trends for the focal species.
- The second focuses on field methods and study design, including a description of the Before-After Control-Impact design, for gathering the metrics needed for the AIOM.
- The third provides a step-by-step demonstration of the AIOM and includes scenarios for applying the method for grassland birds and waterfowl in cases where impact and offset site are of equal biological value as well as where they are not. Scenarios include an application of the AIOM to oil and gas facility impacts, to highlight that the AIOM is not limited to use with wind energy infrastructure.
- The fourth focuses on the decision-support tools, such as spatial modeling applications.

(3) Worksheets that mathematically describe the application of the AIOM to the scenarios described above in the third PowerPoint tutorial, as well as a blank template for users to populate, are available in the appendices of Shaffer et al. 2019.

(4) Decision support tools that can be used to locate offset mitigation sites. There are two modules, one for grassland birds and one for waterfowl; both are available from chuck_loesch@fws.gov.

- The use of the decision support tools to locate mitigation sites is an example of a post-development application, but the decision support tools also can be used pre-development, to compare two potential sites for the need for and cost of potential habitat mitigation.

At least five wind companies in North Dakota are applying concepts from the AIOM in voluntary offset packages. One company moved about half their turbines off native grassland, reducing displacement of grassland birds by 75%. One company is bidding out a proposal to restore 100 grassland acres and 196 wetland acres. Other companies have chosen to pay set dollar amounts to third-party entities, which have some latitude to apply mitigation; e.g., placing easements on native grassland areas to avert future loss.

Audience Questions & Panelist Response/Discussion

Panelists responded to questions within these broad topics:

- Expand on the idea of evaluating future projects on a case-by-case vs. a one-size-fits-all basis.
- What efforts are or could be made to encourage industry participation in addressing cumulative and habitat impacts?

What are the pros and cons of evaluating future projects on a case-by-case vs. a one-size-fits-all basis?

Case-by-case evaluation is important because of the complex nature of grouse populations and how they respond to changes in their habitat. Every population is different – for example, some are migratory, some are not – and the level of existing fragmentation varies from one project to another. A "one-size-fits-all" approach relies on standardized buffer zones, which may miss some things, or may be too large in other cases. "Case by case" gives us flexibility to adapt to individual populations and sites.

There is a major disconnect between policy and the effective management of natural systems. The scientific gold-standard is regionally and site-specific data informing management, but our current policy approach consists of accumulating replicated studies to generate broadly applicable stipulations. We need to shift from that paradigm and instead embrace a consistent process of site- and regional-level monitoring and data-gathering that continuously informs our management decisions. This data also needs to help inform/refine our larger understanding of preservation as we run out of land. Preservation is not going to work as a conservation tool moving forward without a strong component of restoration.

The AIOM formula is based on a suite of species that gave us a displacement rate for grassland bird and waterfowl breeding pairs. Developers or state agencies might make a case that they need to do additional local research to get their own displacement rates for a species that was not one of the original suite; this becomes a negotiation between the agencies and the company or whoever is paying for the additional research. The formula requires knowledge of bird density on both the site that will be developed and the site that will be restored.

What efforts are or could be made to encourage industry participation in addressing cumulative and habitat impacts? *Are there efforts to bring extractive industries into this discussion? Is there any motivation to implement voluntary compensatory mitigation for non-listed species?*

Are there efforts to bring the mining and oil and gas industries into this discussion about cumulative and habitat impacts? This is a huge question; these industries take a lot of space in the west. The gas industry in particular sometimes positions itself as a "greener" form of fossil fuels, but if development of these extractive industries is not curtailed, there will not be room to develop wind resources. For that matter, unless the expansion of wind energy results in (or at least corresponds with) a reduction of fossil fuel development and use, the wind industry cannot take "credit" for reducing climate change. It may be too soon to see a significant shift on the landscape in terms of less oil and gas on the landscape as we build wind.

We also have to keep in mind that it is not just energy production, but the whole range of anthropogenic activities that are driving cumulative effects. Our options are shrinking – both spatially (only so much land) and temporally (running out of time). Cumulative effects is a foundational element of the National Environmental Protection Act (NEPA). Coming up with a population growth metric would be very useful for this discussion.

What might motivate industry to increase voluntary compensatory mitigation for non-listed species? Some companies embrace the "green" label, and are willing to do more voluntary mitigation. For others, the most effective strategy would be to reposition some of the dollars from monitoring of impacts we already understand to research and support of compensatory mitigation. The decision support tools for AIOM can be used up front to reduce the need for compensatory mitigation.

It may also be helpful if we can narrow the range of species we really need to be concerned about. Most of the risks for ferruginous hawks seem manageable, for example, but for hoary bats – no matter what the population size is now – the impacts are going to be such that we will need a more serious curtailment regime to prevent major population impacts at maximum levels of wind build-out. If we can start to eliminate broad swaths of species that would not be as impacted, it may be easier to concentrate on the species we really need to be concerned about.

Closing Remarks

Link to Recording: https://wwrm2020.brand.live/c/live-friday

Our past research meetings have focused on presentations. This year the planning team decided to go deep into a few topics rather than to cover every topic we might have addressed. We asked the panels to focus on *what we know* and *what we need to know*. Our goal is to identify and figure out how to address knowledge gaps for the selected topics without trying to solve all wind-wildlife issues.

Key Themes

The importance of collaboration cannot be overstated.
Again and again we heard about the value and real need for broad collaboration, across geography, employer, and areas of expertise. The Grand Challenges panel was both an example and a reminder that we need to expand our collaborations, bringing social and sustainability experts to the table along with ecologists and engineers.

Time is short, and research and analysis must be purpose-driven.
The pace of change is extreme, and as scientists we need to respond to that or risk irrelevance. Likewise, if we are doing science that no one is using, we are failing. Every piece of research and analysis we conduct needs to be purpose driven, and that means that we need to involve stakeholders in each step of our research process: formulating questions, what data to collect, how to cooperatively and adaptively incorporate/implement those findings.

Other themes (not listed in order of priority):

- *Research Investment* – Some participants suggested shifting our priorities from predicting collision fatalities and other impacts towards investing in research to improve how we mitigate to avoid, minimize, or compensate for wind energy impacts on wildlife.
- *Science-based management* – Can we shift the emphasis from decisions based on "available" science to management that incorporates monitoring and data analysis as part of an iterative cycle? Although the idea of adaptive management is not new, actually accomplishing this may require a paradigm shift, given the role of wildlife trust agencies and our current stipulation-based approach to environmental policy.
- *Listed vs non-listed species* – Several panelists made the point that the species and the impacts currently on our radar may not reflect the range of species and impacts we will be dealing with ten, twenty or thirty years from now. Our regulatory framework focuses attention on listed species, but we need to be thinking more proactively as we plan for future build-out.
- *Factoring in cumulative impacts* – Cumulative impacts are a foundational element of NEPA, but we have difficulty making useful assessments. Can we assess cumulative impacts for wind (or any other single anthropogenic activity) alone, or do they need to be comprehensively addressed, especially if effects of different activities interact?

On Demand Content

Link to On-demand Presentations: https://wwrm2020.brand.live/ondemand

5: Landscape and roost use by spring migrating female Indiana bats (Myotis sodalis)

Presenter: Piper L. Roby (Copperhead Consulting, U.S.)
Authors: Piper L. Roby (Copperhead Consulting, U.S.), Allison G. Davis (University of Kentucky, U.S.), Michael J. Lacki (University of Kentucky, U.S.), Mark W. Gumbert (Copperhead Consulting, U.S.)
Abstract: Landscape use by wild animals is an important topic for land managers and for understanding the ecology of species. Migrating animals pose a challenge in that they are not confined to a home range *per se* and the landscape variables available are likely more extensive than those available to a stationary group of animals. The Indiana bat (*Myotis sodalis*) is a federally endangered regional migrant inhabiting the eastern United States. We aerially radio-tracked individuals during spring migration from hibernacula to summer maternity areas over 9 years to better understand the process and behavior of these bats during an understudied life history event. We identified diurnal roosts during pre-migration staging, along the migration route, and within early use of the summer home range. Of the 137 roosts visited, 1 was a bridge and 136 were 25 species of trees within 10 genera. Four species comprised 63% of all roosts used: *Carya ovata* (n = 53), *Ulmus americana* (n = 13), *Pinus echinata* (n = 10), and *Pinus taeda* (n = 10). Roosts were categorized as either staging, migration, layover, or arrival, and there was no difference in tree metrics (i.e., diameter at breast height, tree height, or roost height). The majority of staging trees were live *Carya ovata* whereas arrival trees were mostly snags of various species. High amounts of useable bark (i.e., bark usable for roosting bats) were found on staging trees and layover trees, but there was no preference for usable bark for migration or arrival trees. In addition, there was no difference between migration trees and those used during summer months in other studies. We determined resource use compared to availability for 20 migrating bats using compositional analysis. Bats used landscape resources, topography, and water as they were available, resulting in high use of forests and low vegetation for all individuals during both foraging and traveling behaviors. Bats used elevation changes as they were encountered, and there was variation among individuals. Although Indiana bats require forests for foraging and roosting, spring migrating bats travel in a relatively straight line from hibernacula to summer grounds with little regard to the landscape cover. This means that band recovery data can provide relatively accurate bat paths that could be considered during the siting process. Due to the opportunistic use of the landscape during migration, turbine placement with regards to land cover may not alleviate mortality. However, avoiding areas known to be in the migration path of Indiana bats could be a useful avoidance measure. Informed placement along with curtailment may be the best options for reducing bat interactions with wind turbines.

11: Use of Camera Technology for Detecting Wildlife Mortality at Wind Turbines

Presenter: Brogan Morton (WILDLIFE IMAGING SYSTEMS LLC, U.S.)
Authors: Brogan Morton (WILDLIFE IMAGING SYSTEMS LLC, U.S.)
Abstract: All wind projects in the U.S. must monitor the mortality of wildlife around the turbines after the plant becomes operational. The current method of determining an onshore wind turbine's impact on wildlife requires biologists to walk transects in plots around the turbines looking for carcasses. This method is not only expensive, it is also extremely imprecise. For offshore wind turbines there are currently no methods for determining impacts, which may cause delays in permitting projects and hinder the burgeoning U.S. offshore wind industry.

Wildlife Imaging Systems is developing an automated wildlife mortality detection system. These systems will precisely quantify the wildlife mortality impacts of the turbines they are installed on, including not only the location of the carcass but the precise time the fatality occurred. The systems will replace the human searchers currently performing the mortality detection for onshore wind projects and for offshore wind projects it will provide a much-needed impact assessment tool since there is currently no way to monitor mortality. In both cases, the systems will provide more precise mortality estimates allowing for better-informed conservation decisions.

The system is comprised of a set of cameras that takes images of the airspace radially outward around the base of the turbine and a video-processing algorithm that identifies free-falling carcasses. Critical to the success of the system is the selection of the right cameras. The trade-off between cost and performance of the cameras is crucial to ensure that the system can both perform its core function of identifying fatalities while also being affordable enough to use as an operational tool, not simply a research tool.

Field evaluation was performed on several types of cameras to determine their fitness for use, including:

- Visible/NIR cameras for security applications
- Visible/NIR cameras for industrial applications
- A thermal camera for security applications

While the system is designed to detect all volant wildlife mortality around the turbine, this evaluation focused on detecting volant wildlife at night, when there is little to no ambient light. This was chosen because it is the most challenging scenario for most imaging equipment.

The field evaluation consisted of launching a surrogate through the field of view of the cameras at a known distance from the cameras while they recorded video. Since some of the cameras use different measurement principles (thermal vs. NIR light) the surrogate was designed to accommodate both types. This process was repeated at multiple distances from 10m to 50m from the camera. The videos were then processed using techniques designed to detect activity in the field of view. The performance of each of the cameras was then characterized by its maximum detection distance. The details of this analysis and results will be presented. In addition to the research results, an introduction to the different video equipment for general wildlife video capture will be presented, including the pros and cons of each type as well as their performance during this testing.

12: An evaluation of the cost-effectiveness of detection dogs and humans for incidental take permit monitoring

Presenter: Meredith Rodriguez (Western EcoSystems Technology Inc., U.S.)
Authors: Meredith Rodriguez (Western EcoSystems Technology Inc., U.S.), Anna Ciecka (Western EcoSystems Technology Inc., U.S.), Jared Studyvin (Western EcoSystems Technology Inc., U.S.), Rhett Good (Western EcoSystems Technology Inc., U.S.)
Abstract: Past studies have demonstrated the effectiveness of detection dogs in difficult terrain, dense or tall vegetation, and in finding small or remnant partial carcasses; however, it is not always clear when the use of detection dogs will be both beneficial to study objectives and cost effective. In 2019, WEST successfully used dog-handler teams to search a combination of mature soybean and cleared plots at projects in Indiana and Illinois. Dog-handler teams achieved searcher efficiencies of 55–73% in mature soybeans and 85% to 88% in cleared plots. Searching soy plots increases the cost-effectiveness of using detection dogs by saving facility operators crop clearing costs. Incidental take permits typically require

monitoring to reach an overall probability of detection given availability of 0.25 (*g*=0.25) in intensive search years. The Midwest Short Term Habitat Conservation Plan Template will require post-construction monitoring to reach *g*=0.2 in the first three years and 0.08 in the last three years. We illustrate, through examples, the differences in costs (hours of effort and crop clearing) between detection dogs and human searchers to reach different levels of detection (g=0.08, 0.2, and 0.25). We found that dogs are likely to be the most cost effective option when g=0.25 or 0.2, but that humans may be most cost-effective at lower intensity levels of monitoring.

13: Sensitive bat species in Colorado and their relative susceptibilities to wind farm impacts

Presenter: Pamela Wegener (Pinyon Environmental, Inc., U.S.)
Authors: Pamela Wegener (Pinyon Environmental, Inc., U.S.)
Abstract: The United States Fish and Wildlife Service Wind Energy Guidelines includes Tier 1, Tier 2, and Tier 3 studies to evaluate the potential likelihood of sensitive bat species to be impacted by wind farm projects. While these assessments are important to informing siting decisions, it can be difficult for developers to acquire information on the geographic distributions of sensitive bat species and the susceptibilities of those species to wind farms. This is particularly true in the western United States, where there is relatively little data on bat populations. Colorado, which passed the first voter-led Renewable Energy Standard in the nation, is a hotspot for wind energy development; however, relatively little is known about interactions with sensitive bat species and wind energy in the state. In this poster, we synthesize information on preferred habitat types, migration routes, and behavior patterns for four species identified by the Colorado Parks and Wildlife State Wildlife Action Plan as of highest conservation concern: fringed myotis (*Myotis thysanodes*), little brown myotis (*Myotis lucifugus*), spotted bat (*Euderma maculatum*), and Townsend's big-eared bat (*Corynorhinus townsendii*). Based on this information, as well as the location of current wind energy development and areas of high resource potential in Colorado, we develop a risk matrix for each of the four Colorado sensitive bat species to turbine-related mortality. We compare our risk matrix with published data on bat fatalities to assess the strengths and weaknesses of using the matrix as a predictive tool for bat fatalities.

14: Understanding the Effects of Offshore Wind Energy Development in the U.S. on Birds and Bats: Identifying Key Research Needs, Mitigation Measures, and Conservation Guidance

Presenter: Kate Williams (Biodiversity Research Institute, U.S.)
Authors: Kate Williams (Biodiversity Research Institute, U.S.), Kate McClellan Press (New York State Energy Research and Development Authority, U.S.), Julia Gulka (Biodiversity Research Institute, U.S.), Gregory Lampman (New York State Energy Research and Development Authority, U.S.), Pamela Loring (U.S. Fish and Wildlife Service Migratory Bird Program, U.S.), Edward Jenkins (Biodiversity Research Institute, U.S.)
Abstract: State policies have become a vital driver of the nascent offshore wind industry in the United States. New York State has emphasized regionally-focused, science-based collaboration to develop guidance and fill data gaps around the potential risks and impacts of offshore wind energy development to wildlife along the east coast of the U.S. Under the auspices of the Environmental Technical Working Group for Offshore Wind (E-TWG), a number of offshore wind developers, managers, environmental advocates, and scientists have been involved in these efforts since 2017. Recent efforts are integrated to provide guidance for research and mitigation at varying levels of methodological detail, including:

- Development of generalizable recommendations to mitigate and monitor impacts to birds and bats during construction and operations of offshore wind facilities in the eastern U.S., with input and consensus from a range of stakeholders.

- Development of a scientific research framework to better understand the impacts of offshore wind energy development on birds and bats. This effort, which built upon monitoring recommendations above, included a multi-day stakeholder workshop in March 2020 to begin identifying key research questions and generating specific hypotheses for project- and regional-level studies. A smaller group of subject matter experts have continued development of the framework, with expected completion in December 2020.
- Identification of key short-term research and coordination needs to help improve our understanding of cumulative impacts to wildlife as the offshore wind industry develops in the U.S. The second State of the Science Workshop on Wildlife and Offshore Wind, in mid-November 2020, focuses on assessing the state of knowledge around cumulative biological impacts from offshore wind energy development and identifying key next steps to improve our understanding.
- Filling data gaps and research/coordination needs. For example, with funding from New York State, a collaborative project is developing guidance for using automated VHF telemetry as part of pre- and post-construction monitoring efforts at offshore wind facilities. Facilitating the offshore application of automated radio telemetry (e.g., Motus Wildlife Tracking System) will help provide valuable information on offshore behaviors and movements in small-bodied bird and bat species, including key species of conservation concern.
- Improving data standardization and transparency. New York State requires environmental data transparency in its offshore wind procurements. In support of this requirement, the state is reviewing existing environmental databases and clearinghouses, to ensure that non-proprietary data collected by offshore wind developers are housed appropriately and made publicly available.

These efforts to understand, avoid, and minimize avian and bat impacts from offshore wind development activities are informing state decision-making, helping to reduce risks for developers, and improving conservation and management outcomes. The effectiveness of these collaborations is due in part to the regional, rather than state-specific, scale of interest; the incorporation of a wide range of stakeholder input with appropriate technical expertise for each effort; and a strong emphasis on the use of science to inform decision-making.

15: Potential ecosystem effects of large-scale implementation of offshore wind in the North Sea

Presenter: Luca van Duren (Deltares, Netherlands)
Authors: Luca van Duren (Deltares, Netherlands), Firmijn Zijl (Deltares, Netherlands), Stendert Laan (Deltares, Netherlands), Thijs van Kessel (Deltares, Netherlands), Vincent van Zelst (Deltares, Netherlands), Lauriane Vilmin (Deltares, Netherlands), Jaap van der Meer (Wageningen Marine Research, Netherlands), Johan van der Molen (NIOZ, Netherlands), Karline Soetaert (NIOZ, Netherlands), Tony Minns (Deltares, Netherlands), Peter Herman (Deltares, Netherlands)
Abstract: The southern North Sea is a relatively shallow shelf sea, subject to intense anthropogenic utilization. All adjacent countries are developing offshore wind farms and have plans for significant upscaling of this renewable technology in the coming decades. The offshore wind industry expects a combined production of wind energy in the southern North Sea of around 212 GW by 2050.
Potential harmful effects of wind farms, such as interference with migration routes, loss of feeding habitat for seabirds, collisions with bats and damaging effects of noise from pile driving on fish and

marine mammals are already being investigated. Recently, it has emerged that the introduction of very large numbers of turbines may influence hydrodynamics as well as fine sediment concentrations and nutrient dynamics beyond the local scale. This may affect fundamental ecological processes, such as primary production: the basis of the marine food web. Indeed, a relaxation of stratification has been measured in two German wind farms. If this effect becomes significant over large parts of the North Sea, large upscaling of offshore wind may have far-reaching effects on the ecosystem. The consequences of these effects may not necessarily be negative, but they may have significant effects on food supply for higher trophic levels, such as fish, seabirds and marine mammals and hence on ecosystem services.

In the Dutch offshore wind ecological programme (WOZEP), we have started the first numerical model exploration to assess which areas of the North Sea may be susceptible to fundamental changes in ecosystem functioning. We have used a suite of coupled models, including a state-of-the-art 3D hydrodynamic model, coupled to a fine sediment-dynamics model and a water quality and ecological model. We have run scenarios without wind farms, with the current wind farms, and a hypothetical scenario with a total offshore wind energy production of slightly over 200 GW, i.e. roughly in line with expectations of the wind industry for 2050. This latter scenario was developed to learn as much as possible regarding the potential effects in different parts of the North Sea and is not directly based on actual development plans. Instead, the placement of the wind farms was chosen to cover different stratification regimes in the North Sea.

Initial assessments indicate that the model reproduces existing measured stratification patterns very well. The large upscaling scenario indeed indicates that potentially significant effects may occur in large areas of the North Sea. These effects may influence the functioning of the North Sea ecosystem. Within this project we try to understand the bottom-up effects of offshore wind on the North Sea food web as well as the potential knock-on effects on higher trophic levels. The current models need further validation to better understand the consequences of specific assumptions. However, this is a very important first step to understand effects that are perhaps not so visible and obvious, but potentially far-reaching.

16: Evaluating model-based approaches to assess collision risk at wind facilities

Presenter: Greg Forcey (Normandeau Associates, Inc., U.S.)
Authors: Greg Forcey (Normandeau Associates, Inc., U.S.), Julia Robinson Willmott (Normandeau Associates, Inc., U.S.)
Abstract A model is a heuristic tool used to understand how a system works and/or to predict one or more outputs based on a series of input parameters. Predictive models focus on producing the most accurate prediction possible while explanatory models focus on understanding the importance of model predictors to the system. Empirical models are built with observational data to understand how the input parameters affect the outputs. Once a model is built, it can often be extrapolated to other areas to be used as a predictive tool using input data to predict outputs that are not known. This approach is in contrast to mechanistic models which are built through a series of mathematical equations used to mimic the details of the actual system. One application of both empirical and mechanistic models is to predict wildlife mortality at wind facilities by predicting collision risk based on pre-construction monitoring data on abundance, behavior, and wind facility characteristics. A collision risk model (CRM) uses model inputs including abundance, behavior, wind turbine characteristics, and topography. The output prediction is typically an annual mortality prediction in units of fatalities/turbine or fatalities/MW. This presentation will provide an overview and comparison of CRMs used to study wind-wildlife impacts, compare select CRMs, and provide recommendations on selecting a CRM based on the

species of concern and wind facility specifications. Information gleaned from the collision risk modeling process can inform and guide decision making to reduce bird and bat collision impacts.

17: Autonomous Eagle Smart Detection, Ground Deterrent and Blade-Event Monitoring

Presenter: Roberto Albertani (Oregon State University, U.S.)
Authors: Roberto Albertani (Oregon state University, U.S.), Kyle Clocker (Oregon state University, U.S.), Cassandra Davis (Oregon state University, U.S.), Matthew Johnston (Oregon state University, U.S.)
Abstract: Specific aspects for improving the coexistence of wildlife with wind turbines deployment are wildlife detection and identification, mitigation measures including smart curtailing, appropriate turbine siting, and equilibration of state and federal conservation guidance. Availability of field data on impacts and theoretical models can assess wildlife presence and risks. These needs apply to both land-based and offshore wind turbines. This presentation will report on the final result of a U.S. DOE Office of Energy Efficiency & Renewable Energy funded project on eagle wind turbines interaction multi-sensor monitoring and deterrent systems, coupled with automatic blade-events detection.

Objectives of the system are: 1) identification of eagles flying in proximity of wind turbines including flight trajectory prediction, 2) eagle visual ground deterrence, and 3) continuous blade monitoring for event detection. Flying-target detection and eagle identification are achieved by processing video streamed by a single miniature, 360^0 vision smart camera in two stages: detection of moving objects, called foreground, and applying a deep convolutional neural network on the foreground for eagle identification. A ground-based visual kinetic deterrent is automatically triggered if the eagle is predicted to fly toward the rotor. Deterrent units are triggered in random order to minimize habituation. A low-power wireless sensors module installed on each blade provides continuous sensing of vibrations and motion for event detection. Images are saved when an event, including wildlife or lighting strike, is detected on any blade.

Results from detection and identification of golden eagles, deterrent system and results from field tests of the fully integrated system on a commercial 1.5-MW wind turbine, including blade-strikes events and simulation flights using an Unmanned Aerial Vehicle (UAV), will be presented. The system is capable of detecting approaching eagles and potentially deterring them from flying in close proximity to wind turbines. The project represents a significant improvement in the potential for wildlife and wind energy interaction minimization strategies, supporting further safe development of the wind energy market.

18: Automated Enhanced Low-Energy Blade Impact Detection with Night Vision and Acoustics Capabilities

Presenter: Roberto Albertani (Oregon State University, U.S.)
Authors: Roberto Albertani (Oregon state University, U.S.), Kyle Clocker (Oregon state University, U.S.), Cassandra Davis (Oregon state University, U.S.), Matthew Johnston (Oregon state University, U.S.)
Abstract: Specific aspects for improving the coexistence of wildlife with wind turbines deployment are wildlife survey and planning mitigation measures when needed including smart curtailing, appropriate turbine siting, and equilibration of state and federal conservation guidance. Availability of reliable field data on impacts and theoretical models can assess wildlife presence and risks in both land-based and offshore wind turbines. Critical to all the above themes is an automatic and reliable system that can provide documentation, in any condition of visibility, on the field performance of mitigation measures or estimation models. Ultimately the availability of a reliable, autonomous blade-impact detection system is highly desirable if not required.

This presentation will report on the current progress of a project funded by the U.S. DOE Office of Energy Efficiency & Renewable Energy on an advanced low-energy collision detection system for avian and bat species specific to offshore wind energy. Current blade-event detection, developed by the Oregon State University team, can work in any conditions of visibility for event detection, on land or offshore. However, limitations exist for the detection of extremely low-energy impacts, typically from bats or small birds, as well as in event documentation in low-visibility environment and extremely long turbine blades.

The project is based on three objectives: 1) collision detection of extremely low energy blade impacts, 2) visual confirmation of events in low-visibility and nighttime conditions, and 3) event imaging over a long blade length. Technology innovations are applied to sensing, data post-processing and event documentation. Vibrations are measured by contact microphones installed at multiple points along the blade, and by on-blade and on-nacelle wide-bandwidth microphones (including ultrasonic). The system includes dual small form factor cameras mounted on each blade for extended depth of field. Low-resolution and high-resolution infrared cameras on the blade will enhance low visibility operations. System design and initial test results will be presented. The project represent a significant improvement in the potential for wildlife and wind energy interaction minimization strategies, supporting further safe development of the wind energy market.

19: Examining the effectiveness of blanket curtailment strategies in reducing bat fatalities at terrestrial wind farms in North America

Presenter: Evan Adams (Biodiversity Research Institute, U.S.)
Authors: Evan Adams (Biodiversity Research Institute, U.S.), Julia Gulka (Biodiversity Research Institute, U.S.), Kate Williams (Biodiversity Research Institute, U.S.)
Abstract: Blanket curtailment of turbine operations during low wind conditions has become an accepted operational minimization tactic to reduce bat mortality at terrestrial wind facilities. Because bats tend to be more active at lower wind speeds, increasing turbine cut-in speed can significantly reduce bat mortality. Site-specific studies have demonstrated that operational curtailment is effective at reducing impacts, but the exact nature of the relationship between increased cut-in speed and fatality reduction in bats remains unclear. In order to evaluate the efficacy of differing blanket curtailment regimes in reducing bat fatality, we examined data from turbine curtailment experiments in the United States and Canada in a meta-analysis framework. We tested multiple statistical models to explore possible linear and non-linear relationships between turbine cut-in speed and bat fatality reduction. Because the overall sample size for this meta-analysis was small ($n = 35$ control-treatment studies from 16 field sites), we conducted a power analysis to assess the number of control-impact curtailment studies that would be needed to better understand the relationship between fatality rate and change in cut-in speed under different fatality reduction scenarios. We also identified the characteristics of individual curtailment field studies that may influence their power to detect fatality reduction due to curtailment. Using a response ratio approach, we found a 56% reduction in fatality rates when using any blanket curtailment strategy that changes the cut-in speed from 0.5 to 3.5 m/s above the control ($p < 0.001$). However, we did not find strong evidence for linear ($p =0\ 0.07$) or non-linear ($p > 0.11$) association between increasing cut-in speeds and fatality reduction. There was a substantial degree of uncertainty in model estimates, both within individual curtailment studies as well as across studies in the meta-analysis framework. The power analyses showed that the power to detect effects in the meta-analysis was low if fatality reductions were less than 50% at the present sample size, and that site-specific conditions like fatality rate and carcass persistence could strongly influence curtailment study efficacy if not accounted for in study design. Synthesizing across all analyses, our results suggest that the effect of

increasing curtailment speed and bat fatality reduction is likely smaller than a 25% reduction per 1 m/s increase in cut-in speed, particularly when differences in cut-in between treatment and control were large; however, this relationship would require additional studies to properly estimate. Based on our findings, we recommend that if blanket curtailment is to be implemented at cut-in speeds greater than 2 m/s above manufacturer settings, as is currently suggested by some regulatory agencies, additional control-impact experiments should be conducted to help understand the relative value of these increased cut-in speeds for reducing bat fatalities. Such experiments should ideally be sited at wind farms with relatively high expected fatality rates and carcass persistence, be carefully designed to maximize the chance of detecting an effect, and use standardized reporting approaches to facilitate future meta-analyses.

20: Effects of wind energy development on pronghorn habitat selection

Presenter: Megan Milligan (U. S. Geological Survey, Northern Rocky Mountain Science Center, 2324 University Way, Suite 2, Bozeman, MT 59715, U.S.)
Authors: Megan Milligan (U. S. Geological Survey, Northern Rocky Mountain Science Center, 2324 University Way, Suite 2, Bozeman, MT 59715, U.S.), Aaron Johnston (U. S. Geological Survey, Northern Rocky Mountain Science Center, 2324 University Way, Suite 2, Bozeman, MT 59715, U.S.), Jeffrey Beck (Department of Ecosystem Science and Management, University of Wyoming, Laramie, WY 82071, U.S.), Kurt Smith (Department of Ecosystem Science and Management, University of Wyoming, Laramie, WY 82071, U.S.), Kaitlyn Taylor (Grouse Mountain Environmental Consultants, 760 West Fetterman Street, Buffalo, WY, U.S.), Embere Hall (Wyoming Game and Fish Department, 1212 S. Adams Street, Laramie, WY 82070, U.S.), Lee Knox (Wyoming Game and Fish Department, 1212 S. Adams Street, Laramie, WY 82070, U.S.), Teal Cufaude (Wyoming Game and Fish Department, 1212 S. Adams Street, Laramie, WY 82070, U.S.), Cody Wallace (Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming, Laramie, WY 82701, U.S.), Geneva Chong (U. S. Geological Survey, Northern Rocky Mountain Science Center, 2324 University Way, Suite 2, Bozeman, MT 59715, U.S.), Matt Kauffman (U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming, Laramie, WY 82071, U.S.)
Abstract: In the face of climate change, wind energy represents an important alternative to high and increasing energy demands, but it has been criticized for disrupting wildlife populations. While bird and bat fatalities due to collisions are the most visible and measurable negative impact of wind energy development, little is known about the effects on other terrestrial species, including large ungulates. Behavioral adjustments, such as altered habitat selection, are a primary way that long-lived species cope with novel disturbances. We evaluated effects of wind energy development on pronghorn (*Antilocapra americana*) space use and habitat selection. Using data from GPS-collared female pronghorn in the Shirley Basin of south-central Wyoming, USA, we tested four hypothetical effects of wind turbines on pronghorn summer and winter space use: 1) displacement away from wind turbines, 2) expansion of home ranges, 3) avoidance behavior within home ranges, or 4) sustained avoidance behavior within home ranges. We monitored 156 individuals over four summers (2010, 2011, 2018 and 2019) and 225 individuals over five winters (2010, 2010/11, 2011/12, 2018/19 and 2019/20) and used resource selection functions (RSF) to evaluate selection relative to turbines after controlling for other habitat factors, such as snow depth. We found that in most years pronghorn were not displaced after turbine construction and that turbines were not related to an expansion of home ranges, although the effect of turbines on both habitat selection and size of winter home ranges varied by year. Within home ranges, we found that some pronghorn avoided wind turbines whereas others selected habitat closer to turbines, and selection for both turbines and other habitat variables was highly variable, which translated to no population-level patterns in either season. Highly variable habitat selection and

movement of pronghorn, both among individuals and across years, may make effects of wind-energy development difficult to detect.

21: Ecosystem service models for onshore and offshore wind development

Presenter: Liz Kalies (The Nature Conservancy, U.S.)
Authors: Liz Kalies (The Nature Conservancy, U.S.), Taylor Ferranti (University of North Carolina, U.S.), Sunny Qiao (World Resources Institute, U.S.)
Abstract: Ecosystem services are the benefits that natural ecosystems provide to humans. These include social and economic benefits, such as jobs, income, improved health, aesthetics, and recreation. Ecosystem services models are detailed visual representations of an ecosystem's effects on all components of the natural system and human systems, and help us understand both intended and unintended consequences of alterations to the environment. We have prepared ecosystem services models for both onshore and offshore wind development in the southeastern United States. We also created detailed evidence libraries that support the models. In this poster, we will share the methods and approach to developing an ecosystem services model, and present the models that we created. They demonstrate positive or negative impacts of wind development on multiple facets of the environment and society, including wildlife, water, economics, human health, and climate.

24: Bioseco Bird Protection System (BPS) polish tool for protection birds of prey at windfarms

Presenter: Aleksandra Szurlej Kielańska (Bioseco; Department of Vertebrate Ecology and Zoology, University of Gdansk, Poland, Poland)
Authors: Aleksandra Szurlej Kielańska (Bioseco; Department of Vertebrate Ecology and Zoology, University of Gdansk, Poland, Poland), Dawid Gradolewski (Bioseco; Department of Mathematics and Natural Sciences, Blekinge Institute of Technology, Karlskrona, Sweden;, Poland), Damian Dziak (Bioseco; Department of Mathematics and Natural Sciences, Blekinge Institute of Technology, Karlskrona, Sweden;, Poland), Adam Jaworski (Bioseco, Poland), Lucyna Pilacka (Bioseco, Poland), Dariusz Górecki (Bird Friendly Investment support association - PTAcom, Poland)
Abstract: Research on the effectiveness of the Bioseco Bird Protection System was carried out at two testing sites in northern Poland from April to October 2019 and from May to October 2020, respectively. A system prototype used at the study site in 2019 was comprised of three detection modules with 180 degrees range, whereas the system used in 2020 was based on eight modules with range of 360 degrees. Bioseco BPS recorded the data of every detection, including i.e.: distance, height, approximate flightpath and size class of the detected object. Visual observations conducted by an ornithologist was focused on daytime activity and movements of birds of prey detected at both the study sites. Total survey time in 2019 was 125 hours, whereas in 2020, 139 hours of field observation were performed. Detection efficiency of birds of prey depends of the body size category and the distance from the turbine. The Bioseco system is characterized by high detection efficiency, especially of birds with wingspan bigger than 1 m, in a distance up to ca. 300 m, for birds up to 1.5 m wingspan in a distance up to 400m, and for big birds with a wingspan over 1.5 m in a distance exceeding 500m.
The highest detection rate during 2019 survey (100%) was noted for large size birds (wing span over 1.5 m) observed in each distance category. Validation conducted in 2020 showed that for the majority of species the detection efficiency was 100%. An exception was common buzzard (*Buteo* buteo) and red kite (*Milvus* milvus) for which the detection efficiency was 88.6% and 91.7% respectively.

While working on the effectiveness improvement of the Bioseco system we put a special emphasis on the reduction of false positive events, meaning objects wrongly classified as birds. False positives were reduced up to 5% in 2019 and 4% in 2020. Further system optimization is underway.

The Bioseco system may be an alternative to periodical turbine shutdowns. The assumption is that, by shutting down the turbine when a big bird is detected in flight at a distance of less than 300m, this would minimize the collision risk to large birds.

25: A decade of post-construction bird and bat monitoring at south-eastern Australian wind farms

Presenter: Elizabeth Stark (Symbolix, Australia)
Authors: Elizabeth Stark (Symbolix, Australia), Stuart Muir (Symbolix, Australia)
Abstract:
Motivations and objectives: Post-construction data from carcass search programs in Victoria, Australia offer an opportunity to understand the collision risks that turbines pose to birds and bats. However, the data is collected on a site basis. The exact objectives and methods change depending on site-specific permit conditions, management plans, and the team of observers used. There are few existing papers about which bird and bat species are most susceptible to collision in Australia, which hampers the ability for strategic, landscape-scale risk planning. Our objective was to develop a combined data set from multiple sites to estimate regional statistics and explore state-wide patterns.
Methods: We compiled a substantial dataset from 10 sites, with a total of 5,432 carcass surveys (2,059 human and 3,373 canine) over 14,746 hectares and 10 years. All sites are located west of Melbourne, in Victoria, Australia. We developed novel methods to combine data and estimate per-turbine mortality from multiple sites and carcass sampling protocols through simulations. These methods open up the ability to investigate influences that extend beyond sites, such as seasonality and turbine size. Using a simulation to estimate mortality allowed us to account for different carcass search protocols (e.g. survey interval and search area). Binomial modelling produced estimates of searcher efficiency and covariance significance. Survival analysis provided estimates of the loss curves and time to loss estimates.
Key results: A total 428 bats and 355 birds were found in the study (approximately one carcass or feather-spot find per 6.9 turbine searches, or one find per 19 hectares). We estimated the annual per-turbine mortality for different species and different turbine sizes. For birds, significantly more fatalities occur at larger turbines, but the rate is not significantly different for bats. Mortality is higher for White-striped Freetail Bats (*Tadarida australis*) than any other bat or bird species in this region. We generated searcher efficiency estimates for humans versus canines. As found in previous studies, dogs are significantly more effective at finding bat carcasses, but the difference is less substantive for medium and large birds. We analyzed the scavenger rate loss profile for different species (including testing the efficacy of proxy species like mice and chickens)
Implications: The results represent the first set of multi-site, regional bird and bat mortality estimates from Australian wind turbines. For the first time, we can estimate the per-turbine mortality for individual species, and compare the incidence of collision for different species. We can also demonstrate the impact of different sized turbine on bird and bat mortality. These results are the first step towards a regional understanding of the cumulative impact of turbines collisions on specific local species.

26: Reducing collision mortality through wind turbine shutdown: creating a predictive bird migration model with 3D radar data

Presenter: Jonne Kleyheeg-Hartman (Bureau Waardenburg, Netherlands)
Authors: Jonne Kleyheeg-Hartman (Bureau Waardenburg, Netherlands), Astrid Potiek (Bureau Waardenburg, Netherlands), Hein Prinsen (Bureau Waardenburg, Netherlands), Willem Bouten (University of Amsterdam, Netherlands), Erik Klop (Altenburg & Wymenga, Netherlands)
Abstract: One of the largest operating wind farms in the Netherlands is located at a hotspot for bird migration and is known to kill about 3,000 birds per year. Almost half of these collision victims concern migrating passerines. Because of this high site-specific mortality rate and the plans for the expansion of

this wind farm, the permitting authorities are seeking ways to reduce the number of collisions of migrating birds. In autumn 2018 and spring 2019, we took part in a major research program with the aim of developing predictive models and protocols for shutdown-on-demand in periods with high nocturnal passerine traffic at rotor height. We used a novel full 3D bird radar to collect information on (nocturnal) bird migration at rotor height. With this innovative dedicated bird radar, we measured the flight behavior of (migrating) birds within and around the wind farm, including spatial and temporal density patterns and flight height profiles at high spatial and temporal resolution. Simultaneously, data of bird migration at much higher altitudes were collected with a nearby weather radar. Collision victim searches were also performed within the existing wind farm before and after nights with expected high migration intensity.

Earlier studies showed that migration of passerines at higher altitudes (above 200 meters) can to some extent be predicted with a bird migration model based on weather radar data. In this study we compared the data collected with the 3D bird radar at rotor height with the data collected with the weather radar at higher altitudes to study the feasibility of the development of a bird migration model for rotor height based on weather radar data. The model will be used to shut down wind turbines during nights with high levels of passerine migration to reduce bird mortality. The moments of shutdown will have to be predicted at least 48 hours ahead to prevent problems with the electricity supply to the grid. We calculated the possible reduction in the number of collision victims that can be realized using different shutdown regimes with a collision rate model (CRM). The results of the collision victim searches were used to calibrate these CRM calculations. We show that it is possible to develop a predictive model for passerine migration at rotor height. As a next step the Dutch government is seeking ways to expand the model for nationwide applicability.

28: Optimal bat curtailment: A data-driven strategy to sustain bat populations while minimizing curtailment losses

Presenter: Jonathan Rogers (Persimia, LLC, U.S.)
Authors: Jonathan Rogers (Persimia, LLC, U.S.)
Abstract: Smart curtailment techniques have been developed by several organizations throughout the wind community over the past several years, with the goal of minimizing bat fatalities while also maximizing power production and revenue. However, although smart curtailment often attempts to minimize bat fatalities as much as possible, it is likely that bat populations can be sustained by limiting fatalities only to a certain level. This notion that fatalities do not necessarily need to be eliminated entirely, but rather need to be sustained below a certain threshold, leads to new opportunities for curtailment optimization. This talk will present a so-called *optimal curtailment* technique that is a generalization of smart curtailment. In optimal curtailment, operational hours are used strategically throughout the year so as to maximize energy production and revenue, while meeting constraints on acceptable levels of wildlife impact. Note that this notion of “optimal curtailment” differs from smart curtailment in that it uses operational hours strategically even if bats are present, as long as the total number of predicted bat fatalities per year is held at or below an acceptable level.

Optimal curtailment uses meteorological data, energy demand data, and models of bat occupancy to predict time periods during the year when energy demand is high and wind resource is likely to be available. At each nighttime hour, bat occupancy models (and optionally, in-situ devices such as echolocation sensors) are used to predict whether bats are present and to compute a probability distribution over the number of fatalities that would result from operating. Based on current wind conditions and energy demand, an optimal control algorithm determines whether the turbine should be

curtailed during the current hour, or whether an operating hour (and potential bat fatalities) should be saved for a future time when energy demand or wind resource may be higher. The algorithm that underlies optimal curtailment comes from the domain of stochastic optimization. In particular, the problem is framed as a Markov Decision Process under uncertainty and solved using an optimization technique called dynamic programming. This solution technique takes advantage of the large meteorological and energy demand data sets that are often available for current wind projects as well as those under development.

This talk will present the overall methodology behind optimal curtailment and its relationship to smart curtailment. High-level descriptions of the underlying mathematics and required data sets will be presented. Example results will be provided for a notional wind site in California using actual meteorological and energy demand data, as well as bat occupancy models based on recent literature. Results show that optimal curtailment is successful in maintaining average yearly bat fatalities below an acceptable threshold while maximizing revenue. Furthermore, a comparison between optimal and smart curtailment strategies is presented, showing that the optimal strategy reduces curtailment losses further while also ensuring the sustainability of bat populations. Overall, these results illustrate the promise of optimal curtailment as a means to minimize curtailment losses and sustain bat populations through the use of advanced algorithms, large data sets, and in-situ sensing.

30: Estimating cumulative numbers of collision victims, and impact assessment on population level

Presenter: Astrid Potiek (Bureau Waardenburg, Netherlands)
Authors: Astrid Potiek (Bureau Waardenburg, Netherlands), Abel Gyimesi (Bureau Waardenburg, Netherlands), Ruben Fijn (Bureau Waardenburg, Netherlands), Jacco Leemans (Bureau Waardenburg, Netherlands)
Abstract: The development of offshore wind industry in the Netherlands started in 2002, and since then four offshore wind farms with a combined capacity of around 1 gigawatt have become operational. In the upcoming decade, planned developments will increase this capacity to 11 gigawatts by 2030. The vast growth in offshore wind farms increases the need for appropriate assessments of cumulative environmental impacts. Over the past years, various national and international initiatives were developed, aiming at the quantification of the cumulative effects of these developments on birds, bats and marine mammals (MEP-NSW, Wozep, SEANSE). These studies addressed different aspects of cumulative impacts on a larger scale rather than on the scale of a single wind farm, which is a crucial prerequisite for an appropriate impact assessment. Different scenarios of wind farm developments are taken into account, for example projecting the impact of all wind farms planned until 2030. Within these studies, the numbers of victims of these wind farms are estimated using, among others, density maps and bird collision models. Moreover, in addition to numbers of victims, the impact assessment should give insight in the expected impact on the population level. Within the Wozep programme, the impact on population level was assessed for twelve selected species using matrix population models. These species include migratory as well as resident birds.

We present the results of several studies regarding the estimation of cumulative numbers of collision victims for the southern and central North Sea. These population models project the population trend based on demographic rates, in our case for 30 years. The comparison of the scenarios with and without additional mortality due to turbine collisions provides input for the impact assessment. We present different ways to quantify the impact on the population level. This includes differences in median outcome between the impacted and unimpacted scenario, as well as the probability of a 10% decline for both scenarios. Finally, we discuss how we can further improve the methods of cumulative impact

assessments in the near future, for example by means of individual-based models. We are currently developing an individual-based model, which can be used to include differences in flight behavior between individuals (for example based on age class or sex).

31: Preliminary results on effectiveness of an ultrasonic acoustic deterrent from bat flight cage trials

Presenter: Brittany Stamps (Texas State University, U.S.)
Authors: Brittany Stamps (Texas State University, U.S.), Emma Guest (Texas State University, U.S.), Sara P. Weaver (Bowman Consulting Group, U.S.), Amanda Hale (Texas Christian University, U.S.), Cris D. Hein (National Renewable Energy Laboratory, U.S.), Brogan Morton (WILDLIFE IMAGING SYSTEMS LLC, U.S.), Janine Crane (NextEra Energy Resources, U.S.), Bethany Straw (National Renewable Energy Laboratory, U.S.), Mark Chaffee (NRG Systems, U.S.), John Ugland (NRG Systems, U.S.), Sarah Fritts (Texas State University, U.S.)
Abstract: Collisions with wind turbines result in hundreds of thousands of bat fatalities annually in the United States and Canada, with peak fatalities occurring during fall migration. Wider implementation of minimization strategies to reduce bat fatality is likely to occur if consistent effectiveness and cost feasibility are proven. The development of a viable ultrasonic acoustic deterrent (UAD), designed to 'jam' bat echolocation calls and create unattractive air space, allows for the normal operation of wind turbines (i.e., no need for curtailment); thus, UADs may represent a more flexible impact reduction strategy that can be implemented for a wider range of conditions and species assemblages while maximizing renewable energy production. Variations in effectiveness may be due to higher frequency sounds attenuating faster than lower frequencies or due to some bats not encountering deterrent sounds within their characteristic frequency range at greater distances from turbine blades. Additionally, some bat species may be more plastic in their echolocation signatures, allowing them to alter call frequencies for echolocation and prevent sounds emitted from UADs to effectively jam their calls. Our broad objective was to maximize species effectiveness of the NRG Systems-manufactured UAD through controlled, experimental trials in a 60 m x 10 m x 4.5 m (L x W x H) outdoor flight cage located in San Marcos, Texas, USA. Specifically, we released wild-captured bats into the flight cage and tracked flight and echolocation behavior during three, four-minute trials of various sound emissions: low (20–32 kHz), high (38–50 kHz), and combined (20–50 kHz) frequencies, each interspersed by four-minute control periods with UADs powered off. We selected these treatments because the combined configuration is currently used at various wind energy facilities, but data collected to date suggest species-specific differences in demonstrated effectiveness. We quantified the time bats flew within demarcated distances from the UAD using thermal cameras and compared echolocation signatures (duration, frequencies) among treatments using six bat detectors positioned longitudinally within the flight cage. We predicted: 1) bats would spend less time near the operating UAD; 2) some bat species will decrease echolocation duration or call frequencies during UAD emission; and 3) results will differ between fall and spring seasons, potentially coinciding with migration and reproductive behaviors. We conducted trials in October 2019, March 2020, and July-October 2020. To date, we have completed trials on 36 eastern red bats (*Lasiurus borealis*), 4 southern yellow bats (*Lasiurus ega*), 5 northern yellow bats, (*Lasiurus intermedius*), 88 cave myotis (*Myotisvelifer*), 52 evening bats (*Nycticeius humeralis*), 15 tri-colored bats (*Perimyotis subflavus*), and 71 Brazilian free-tailed bats (*Tadarida brasiliensis*). Preliminary results indicate species variations in both flight and echolocation behavior during UAD emissions. Results will provide informative guidance on the efficacy of UADs to prevent bat collisions with wind turbines, providing further insight to continue improving the technology. Here, we will present data on 20 *Lasiurus borealis* trials completed in fall 2020.

32: Assessing Population-Level Consequences of Wind Energy on Birds

Presenter: Todd Katzner (U.S. Geological Survey, U.S.)
Authors: Todd Katzner (U.S. Geological Survey, U.S.), Missy Braham (Conservation Science Global, U.S.), Tara Conkling (U.S. Geological Survey, U.S.), Jay Diffendorfer (U.S. Geological Survey, U.S.), Adam Duerr (Conservation Science Global, U.S.), Scott Loss (Oklahoma State University, U.S.), David Nelson (University of Maryland, U.S.), Hannah Vander Zanden (University of Florida, U.S.), Julie Yee (U.S. Geological Survey, U.S.)
Abstract: Human activity influences birds. However, the ecological and conservation significances of these influences depend on population-level consequences and are thus difficult to predict. This difficulty arises partly because of information gaps and partly because the data on stressors are usually collected in a count-based manner (e.g., number of dead birds) that is difficult to translate into rate-based estimates important to infer population-level consequences (e.g., changes in mortality rates). Here we synthesize tools from multiple fields of study to propose an overarching, spatially-explicit framework to assess population-level consequences of wind energy on birds. A key component of this process is using ecological information from affected birds to upscale from count-based field data on individuals to rate-based demographic inference. The steps to this framework are (1) collect field-based measurement of the effect of wind energy on individual raptors; (2) characterize the location and size of the populations of origin of affected raptors; (3) model demographic rates for those populations; and (4) assess the significance of wind energy-induced changes in demographic rates. We illustrate application of these steps for red-tailed hawks impacted by collision with wind turbines, using stable hydrogen isotope data to infer a “catchment area” describing the geographic origins of affected individuals to estimate population size for that region. Surprisingly, these examples reveal unexpectedly large risks from wind for this species, despite the fact that it is common and widely distributed. This example also illustrates important areas for subsequent theoretical and technical development to make this framework more broadly applicable.

33: Effects of turbine design on bird and bat fatalities at wind energy facilities in Ontario, Canada

Presenter: Alexandra Anderson (TRENT UNIVERSITY, Canada)
Authors: Alexandra Anderson (TRENT UNIVERSITY, Canada), Catherine Jardine (Birds Canada, Canada), Ryan Zimmerling (Environment and Climate Change Canada, Canada), Christina Davy (Ontario Ministry of Natural Resources and Forestry, Canada)
Abstract: Wind turbine hub height, rotor diameter, and power capacity have increased over the past 20 years, but the effects of different turbine designs on bird and bat fatalities are not well understood. We examined the effects of wind turbine design on bird and bat mortality at wind turbines across Ontario, Canada, by using data from the Wind Energy Bird and Bat Monitoring Database, which contains post-construction wildlife monitoring data from wind energy facilities during 2011- 2019. We used GenEst to estimate species-specific bird and bat mortality at individual wind turbines each year and then used zero-inflated generalized linear mixed effects models to examine the relationship between bird and bat mortality and turbine design features. Preliminary results indicate that changes in wind turbine design may result in changes in mortality for some species but not others. Understanding the relationship between wind turbine design and mortality of bats and birds will help guide design selection decisions for the construction and repowering of wind energy projects and help identify actions that may reduce the impacts of wind energy on wildlife.

35: Temporal, topographic, and meteorological correlates of Golden Eagle flight behavior in California's Tehachapi Wind Resource Area

Presenter: Michael Kuehn (AECOM, U.S.)
Authors: Michael Kuehn (AECOM, U.S.), Loren Merrill (AECOM, U.S.), Peter Bloom (Bloom Research, Inc., U.S.), Erin Riley (AECOM, U.S.)
Abstract: The clear environmental benefits of renewable energy must be considered in the context of environmental impacts, and operational wind energy facilities are often faced with the need to balance the two, while maximizing energy production. Like other large soaring birds, golden eagles (*Chrysaetos aquila*) are particularly vulnerable to mortality arising from collisions with operating wind turbines. Improving our understanding of the factors that influence turbine collision risk in golden eagles can help minimize impacts to this protected species, while maximizing energy production. We used flight data collected from eagles equipped with satellite GPS-GSM telemetry units to evaluate potential temporal, topographic, and meteorological correlates of collision risk. The Study Area included the Pine Tree Wind Farm in Kern County, California and all areas within 10 miles. Telemetry data were collected between 2017 and 2019 from six eagles captured within the Study Area, including four adults and two juveniles. Eagle flight height was evaluated in relation to the Turbine Placement Zone (TPZ), defined as the volume of space extending from 0 to 150 meters above ground level across the entire Study Area. The amount of time eagles spent flying overall, and the probability of flight within the TPZ were considered indicators of turbine collision risk. We used generalized linear mixed models and an AIC model comparison approach to assess the relationships between potential predictor variables and response variables. Specific predictors included meteorological variables (wind speed, wind eastness, and wind northness) and temporal variables (month of year and time of day), and terrain variables (elevation, slope, aspect eastness, and aspect northness), as well as key interactions such as those involving wind speed by slope, terrain aspect by wind direction. Weather data were collected from meteorological towers located on the Pine Tree Wind Farm.

Preliminary results indicate eagles spent the most time in flight (versus perched) during the midday period, followed by the late day period, and finally the early day period. The strongest predictors of eagle flight within the TPZ were related to wind direction and terrain aspect, and particularly the interaction between the two. Eagles flying over west-facing terrain were more likely to fly within the TPZ when the wind direction was westerly, while the opposite pattern was observed for eagles flying over east-facing terrain. A similar effect was observed for north- and south-facing terrain when winds were from the north versus south. Eagles were also more likely to fly within the TPZ over areas with steeper slopes and higher elevations, and when wind speed was higher. Although eagles spent the least amount of time flying (versus perched) during the early day period, they were most likely to fly within the TPZ (versus flying above TPZ) during the early day period, followed by the late, then midday periods.
The results from this study to, in combination with prior and current research on eagle collision risk, can help inform turbine siting decisions or operational curtailment procedures to minimize risk to eagles while maximizing energy production.

36: Offshore bat activity patterns detected by vessel-based acoustic monitoring

Presenter: Nathan Schwab (Tetra Tech, U.S.)
Authors: Katelin Craven (Tetra Tech, U.S.), Nathan Schwab (Tetra Tech, U.S.), Derek Hengstenberg (Tetra Tech, U.S.)
Abstract: Current understanding of offshore bat activity and behavior is limited. Tetra Tech conducted acoustic bat monitoring within the Bureau of Ocean Energy Management's Renewable Energy Lease Area OCS-A 0512 (Lease Area) for development of an offshore wind project planned to be approximately

16 nautical miles east of Monmouth County, New Jersey. Bat detectors mounted at the top of a roving offshore research vessel confirmed presence of three bat species (eastern red bat, silver-haired bat, and big brown bat) between May 29 and December 2, 2018. A total of 584 bat passes were recorded within the Lease Area and identified to the species level or frequency group, with a minimum of zero passes and a maximum of 133 passes recorded in a single night. This resulted in 3.1 mean bat passes per detector night, lower than most bat activity rates reported from onshore environments. Detection rates for all species were highest in early August through early November, consistent with migration periods for migratory tree bats. Regression analyses were completed for temperature, wind speed, and date to investigate correlations for the number of bat passes per night with weather data collected from the National Oceanic and Atmospheric Administration's National Data Buoy Center. The regressions yielded a non-significant positive correlation of temperature with the number of bat passes per night ($r=0.69$, $p=0.49$) and a significant negative correlation of wind speed and number of bat passes per night ($r=-2.28$, $p = 0.02$). Seventy-seven percent of all bat passes were detected at average nightly windspeeds below 8 meters per second. This survey indicates that the Lease Area is used by non-migratory bat species (big brown bats), as well as long-distance migrants (eastern red bat and silver-haired bat) with the highest detection rates during the fall of the study period (84%, September–November). No myotis species (which includes northern long-eared bat, eastern small-footed bat, and little brown bat) were confirmed acoustically during the survey. Migratory tree bats represented 70% of the total bat passes recorded, with detections spread across the Lease Area. Short single night spikes in the number of bat passes by the eastern red bat, silver-haired bat, big brown bat, and unidentified high frequency bat in September and October may suggest fall migration pulses across the Lease Area; however, it may also result from an individual bat foraging around the ship during the night so that it could periodically roost and rest on the ship, as has been observed in offshore environments. Although the understanding of offshore bat activity and behavior is limited; migratory tree bats have been the most common species observed offshore, which is consistent with the results of this study.

37: Bigger not necessarily better when repowering: mortality scales with energy production

Presenter: Manuela Huso (U.S. Geological Survey, U.S.)
Authors: Manuela Huso (U.S. Geological Survey, U.S.), Tara Conkling (U.S. Geological Survey, U.S.), Daniel Dalthorp (U.S. Geological Survey, U.S.), Melanie Davis (U.S. Geological Survey, U.S.), Heath Smith (Rogue Detection Teams, U.S.), Amy Fesnock (U.S. Bureau of Land Management, U.S.), Todd Katzner (U.S. Geological Survey, U.S.)
Abstract: As improvements in wind power technology lead to larger turbines capable of extracting power from the wind at ever lower windspeeds, often it is economically advantageous to replace older models with new models. Compared with turbines typically installed in the 1980s, modern turbines are of mono-pole rather than lattice construction, have higher hubs, faster tip speeds, and longer blades that sweep a far larger area and reach higher into the aerosphere. It may seem intuitive that larger, faster blades will cause greater mortality per turbine than smaller, slower ones. However, because larger turbines are installed at lower densities with blades higher above the ground, it is unclear how site-level mortality will be affected by repowering. We investigated how wind turbine-caused wildlife mortality would be affected by the widespread practice of repowering, i.e., replacing smaller, densely spaced, with larger, widely spaced turbines at the San Gorgonio Pass Wind Resource Area over 355 days in 2018-2019. We monitored avian and bat mortality and measured power production at five strings of turbines representing a gradient of power-generating capacity that generally correlates well with many measures of turbine size, e.g., blade length, rotor-swept area (RSA), hub height, maximum blade height. Measuring mortality at different-size turbines within a small area over the same period controlled for variation that can confound comparisons among locations and years. We estimated avian and bat

mortality and 95% confidence intervals at each string using GenEst. Mortality per turbine was higher for larger turbines, but, with the exception of bat mortality at a site close to ponds, mortality per unit power produced was relatively constant across turbine sizes. This suggests that if energy production remains constant, there is no advantage or disadvantage to wildlife of replacing older turbines with newer ones: mortality at a site depends on how much energy is produced, not the size of the turbines producing it. Standardizing mortality estimates by actual energy produced could improve models seeking to understand the regional and site-specific differences in wildlife mortality.

39: Predicting annual variation at large spatial scales in at-sea foraging distribution of a mobile seabird of high conservation value

Presenter: Rob van Bemmelen (Bureau Waardenburg, Netherlands)
Authors: Rob van Bemmelen (Bureau Waardenburg, Netherlands), Chris Thaxter (BTO, United Kingdom), Geert Aarts (Wageningen Marine Research, Netherlands), Mark Collier (Bureau Waardenburg, Netherlands), Mardik Leopold (Wageningen Marine Research, Netherlands), Martin Baptist (Wageningen Marine Research, Netherlands), Ruben Fijn (Bureau Waardenburg, Netherlands)
Abstract: The Sandwich Tern (*Thalasseus sandvicensis*) is an International Union on Conservation of Nature (IUCN) Red List species that has been identified as potentially sensitive to the development of offshore wind farms. Therefore, knowing the spatial overlap between its foraging areas and offshore wind farms is critical to both conservation and spatial marine planning. This is complicated as Sandwich Terns typically show low breeding site fidelity, resulting in annual changes in the distribution and size of colonies and therefore also their at-sea distribution. Here, we predicted the annual at-sea foraging distribution during breeding across the southern North Sea for the years 2010-2019, based on multi-colony GNSS tracking data from five colonies in the UK and the Netherlands and annual colony counts across all colonies around the southern North Sea. In a first step, trips were segmented into commuting and foraging parts. Subsequently, environmental characteristics (water depth, sediment type, sea surface temperature, salinity, flight distance to/from the colony) of foraging locations were compared with random locations within reach of the birds – an RSF modelling approach - to infer habitat selection. This habitat model was then used to predict the annual at-sea foraging distribution of colonies around the southern North Sea, enabling the assessment of potential overlap with offshore wind farms while considering inter-annual variation.

41: Avian and Bat Mortality Patterns at Wind and Solar Energy Facilities

Presenter: Wallace Erickson (West Inc., U.S.)
Authors: Wallace Erickson (West Inc., U.S.), Daniel Riser-Espinoza (West Inc., U.S.), Karl Kosciuch (West Inc., U.S.), Shay Howlin (West Inc., U.S.), Fawn Hornsby (West Inc., U.S.)
Abstract: West has developed one of the most comprehensive databases of post-construction avian and bat mortality studies at both solar and wind energy facilities. From this database, we summarize, compare and contrast patterns in the species composition, fatality rates and other metrics at solar and wind energy facilities. We compare extrapolated estimates from solar and wind estimates to other estimates from other anthropogenic sources of mortality. We also discuss the issue of background mortality, including circumstances when it is an important consideration in fatality studies.

42: Bat Fatality Timing at Wind Farms across the Continental U.S. and Canada

Presenter: Kevin Murray (West Inc., U.S.)
Authors: Wallace Erickson (West Inc., U.S.), Fawn Hornsby (West Inc., U.S.), Kevin Murray (West Inc., U.S.), Christian Newman (EPRI, U.S.), Shay Howlin (West Inc., U.S.)

Abstract: Defining peak bat fatality periods is an important first step in developing cost effective measures to avoiding and minimizing bat fatalities at wind farms. Knowledge of annual variation and other key factors influencing the timing of bat fatalities can be used to predict high-risk periods to design risk minimization strategies including smart curtailment. Numerous studies have shown most bat fatalities occur in the late summer and early fall (mid-July to early September), a time period associated with fall migration and mating for bat species from the temperate regions of North America and Europe. However, there is very little information available on the species-specific timing of bat fatalities as well as more refined periods of risk. While the relevant data has been collected for most fatality studies at wind projects in North America, review and synthesis of these data is lacking. We use a dataset of 175 publically-available studies from 133 wind energy facilities across the continental U.S. and Ontario, Canada from 1996 to 2018 to examine the timing of bat fatalities of three species of bats commonly found as turbine-related fatalities - hoary bats, eastern red bats, and silver-haired bats. Our dataset confirms the common pattern of peak fatalities in the late summer and early fall for all bat species combined. In addition, our data indicates there is broad overlap in timing of fall fatalities between hoary bats and eastern red bats and a trend of silver-haired bat fatalities occurring later in the fall. At projects with multiple years of study, there is often substantial overlap in the timing of peak fall fatalities among years, but the timing can vary by one to a few weeks and the duration of peak fatalities can vary as well. Finally, we found evidence the fall timing of hoary bat fatalities is correlated with longitude, with fatalities occurring later as project locations move westward. This result may indicate the broad trend of westward migratory movements in the hoary bat is related to the observed fatality timing in this species.

43: A Review of the Issues of Uncertainty in Cause of Death and Background Mortality in Avian Fatality Monitoring Studies.

Presenter: Daniel Riser-Espinoza (West Inc., U.S.)
Authors: Wallace Erickson (West Inc., U.S.), Daniel Riser-Espinoza (West Inc., U.S.), Karl Kosciuch (West Inc., U.S.)
Abstract: Wildlife monitoring efforts at large-scale wind and solar energy facilities are often designed with the goal of estimating seasonal or annual avian fatality rates caused by collision with the infrastructure of those facilities. Searcher efficiency, scavenging, and plot size bias are typically incorporated into adjusted fatality estimates to account for carcasses that may have been missed or not present during searches. However, in many cases, the actual cause of the fatality is unknown due to the poor condition of the carcass, and conservatively assumed to be caused by the facility. We provide a comprehensive literature review on the issue of the potential bias associated with background mortality (mortality not due to the facility) in avian fatality studies associated with renewable energy. We summarize, in detail, the field studies that have been conducted to measure background mortality and discuss their implications and limitations. We also summarize readily available data on cause of death from WEST's existing database of wind and solar project avian fatality records. From these data, we provide a qualitative assessment of the potential magnitude and importance of the bias in fatality estimates by taxa where sufficient data exist, with a clear description of the assumptions and limitations in these estimates. We also provide recommendations of what studies should be conducted to fill important data gaps. Based on studies associated with wind and solar facility fatality monitoring, reference fatality estimates have ranged from 0.024 birds/ac/yr to 2 birds/ac/yr and when compared to the facility estimates, ranged from 6% to over 90% of facility estimates.

47: Improved behavioral classification of flight behavior informs risk modeling of bald eagles at wind facilities in Iowa

Presenter: Silas Bergen (Winona State University, U.S.)
Authors: Silas Bergen (Winona State University, U.S.), Manuela Huso (U.S. Geological Survey, U.S.), Missy Braham (Conservation Science Global, U.S.), Adam Duerr (Conservation Science Global, U.S.), Todd Katzner (U.S. Geological Survey, U.S.), Tricia Miller (Conservation Science Global, U.S.), Sara Schmuecker (U.S. Fish and Wildlife Service, U.S.)
Abstract The Upper Midwest houses one of the densest populations of breeding and wintering bald eagles in North America, with dramatic increases in their numbers occurring over the last 30 years. Coincident increase in wind turbine density in these areas has increased bald eagle exposure to risk from wind energy. As a result, more bald eagles have been killed at renewable energy installations in Iowa than in any other state in the USA. Despite this, in the USFWS Eagle Conservation Plan Guidance, information used to predict mortality, and thus to determine permitted take, is predominantly extrapolated from data on ecologically and behaviorally different golden eagles. Effective management of bald eagles depends on improved species-specific information regarding how, when, where, and why bald eagles move across the landscape during each life stage and ultimately on some type of model of risk of negative interactions with renewable energy developments and associated infrastructure in specific landscapes. We used GPS telemetry data collected at ~6-7 second intervals from ~80 bald eagles tagged in and around Iowa. We used k-means clustering to classify movement behavior to inform models of risk to bald eagles from wind turbines. Preliminary results suggest five primary behavioral modes of eagles. We identified two behavioral modes at higher altitudes in thermals, associated with ascending and descending flight. Three other behavioral modes were at lower altitudes; these included use of deflected air, flapping flight, and perching behavior. Some behavioral modes are associated with specific landscapes, others occur more generally across the landscape. Understanding these behavioral modes and their habitat associations provides a framework for predicting levels of risk birds may face from turbines in different landscapes.

48: Migratory bird twilight ascent and descent rates along the southwestern shoreline of Lake Erie

Presenter: Michael Wellik (U.S. Geological Survey, U.S.)
Authors: Michael Wellik (U.S. Geological Survey, U.S.), Eileen Kirsch (U.S. Geological Survey, U.S.), Mark Shieldcastle (Black Swamp Bird Observatory, U.S.)
Abstract: When nightly migration starts or ends, birds transition vertically through the airspace where there is the potential for collision with anthropogenic structures. Factors that increase collision risk include reduced visibility because of bad weather, size and/or orientation of the object, time spent in the collision zone and proximity to large concentrations of birds or important habitat areas. The forested wetlands along the southwestern shore of Lake Erie support important concentrations of nocturnal migrant songbirds during spring and fall migration. Inland woodlots are also important to migrant birds in this largely agricultural landscape. We estimated rates of ascent and descent of (presumed) birds as low as 40m above ground level during two years of spring and fall migrations using an X-band marine radar with a vertically rotating open array antenna. Radar placement on the shoreline allowed us to analyze movement 1.5km onshore and offshore. We used the program radR, to develop nightly track profiles from which we summarized overall altitude distributions, in addition to the rates of ascent and descent during the dusk and dawn time periods. We summarized ascent and descent rates by quantiles for low altitude (40-200m AGL) movement. With these estimated ascent and descent rates we then calculated the horizontal distance to achieve altitudes above a 1.5MW wind turbine. As an exercise to demonstrate locations where turbines might more safely be placed in this landscape we used GIS to place buffers around wooded areas based on the modeled horizontal distances. These buffers revealed

the extent of landscape from wooded areas which might be of collision risk for nocturnal migrant birds stopping over in woodlots and forests. Buffers based on the confidence intervals may assist in siting windfarms, for example setting setbacks near important woodlots and forests.

49: A new physics-based model for guiding bat carcass surveys at wind turbines

Presenter: Shivendra Prakash (University of Iowa, U.S.)
Authors: Shivendra Prakash (University of Iowa, U.S.), Corey Markfort (University of Iowa, U.S.)
Abstract: We propose a new model for computing bat fatalities at wind turbines to guide carcass surveys and correct take estimates for surveys with limited coverage. Current approaches for guiding carcass search radius estimation are based on statistical analysis of prior survey data, which can result in an inappropriate search area. Additionally, studies relying only on empirical data are limited to the specific wind turbine models and bat species included in the dataset. By considering a physics-based approach, the new model can provide insights about the effect of the governing parameters on the likely carcass fall zone distribution. A robust and economically efficient model is needed to guide surveys for wind farm operators to determine the extent turbines adversely impact threatened and endangered species and to evaluate the environmental effects of wind power projects. The new model is based on the hypothesis that the distribution of where bat carcasses fall after collision with wind turbines is sensitive to the variation in biophysical and aerodynamic properties of bats, wind turbine size and operational characteristics, and wind speed. The resulting ballistics model is introduced for simulating bat carcass trajectories after impact with wind turbine blades. The model can also be used to infer the behavior of bats near wind turbines to better predict the risk of collision between bats and turbine blades.

This research consists of three phases: In the first phase, we for the first time measure the aerodynamic properties of bat carcasses, including terminal velocity and drag coefficient, of three bat species using high-speed imaging of carcass drop experiments[5]. In the second phase, a 3-D ballistics model was developed by including bat collision properties, wind velocity and turbine blade rotation rate to determine the bat likely strike locations on the rotor plane, using SCADA and carcass survey data. In the third phase, we demonstrate use of Monte-Carlo simulations of the new ballistics model and introduce a methodology for estimating bat fate for the migration season. The Monte-Carlo based ballistics model provides a robust framework for guiding the carcass surveys for full migration seasons involving different bat species, meteorological and turbine operational conditions. This tool can also be used for correcting carcass survey data for limited or unsearched areas.

51: Flight behavior of Golden Eagles in Wyoming: Implications for wind power

Presenter: Tricia Miller (Conservation Science Global, U.S.)
Authors: Tricia Miller (Conservation Science Global, U.S.), Michael Lockhart (Wildlands Photography and Bio-Consulting, U.S.), Missy Braham (Conservation Science Global, U.S.), Brian Smith (U.S. Fish and Wildlife Service, U.S.), Todd Katzner (U.S. Geological Survey, U.S.)
Abstract: Understanding flight behavior in relation to temporal and weather variables is an important component of conservation and management of golden eagles at wind facilities. Since June 2017, we have tagged 45 golden eagles (21 adults and 24 sub-adults) with GSM/GPS telemetry units in and around

[55] Prakash, S. and Markfort, C. D. (2020). Experimental investigation of aerodynamic characteristics of bat carcasses after collision with a wind turbine. Wind Energ. Sci., 5, 745–758, https://doi.org/10.5194/wes-5-745-2020.

wind energy facilities in Wyoming. The units were programmed such that when the birds were in flight, they collected high temporal resolution GPS data (<7 s) at least 3 days per week. From June 2017 – June 2019, we collected >5 million GPS locations and collected high resolution flight data on 4,465 eagle days. We calculated a suite of flight characteristics for each bird each hour. We expected that certain characteristics of flight below 200 m above ground level, namely, longer flight times, higher flight path tortuosity, and higher variation in flight altitudes, increased vulnerability and risk of exposure to wind turbines. We examined how each of these responses was influenced by time of day, time of year, and weather. Preliminary results showed that longer flight times were associated with conditions supporting thermal and orographic updrafts. Tortuosity of flight paths was highest when conditions did not support thermal soaring. Finally, we found that variation in flight altitude was greatest when conditions supported thermal soaring. Our results suggest that predicting risk from telemetry data will be most accurate when it incorporates multiple responses in order to better understand when golden eagles may be at risk for collision with wind turbines in Wyoming.

52: Elasmobranchs and EMFs: An evaluation of the potential cumulative effects of electric and magnetic fields (EMFs) from offshore wind development on elasmobranchs in the Massachusetts Wind Energy Area

Presenter: Cristen Mathews (DNV GL, U.S.)
Authors: Cristen Mathews (DNV GL, U.S.), Sarah Aftergood (DNV GL, U.S.), Amanda Klehr (DNV GL, U.S.), Kimberly Peters (DNV GL, U.S.)
Abstract: Offshore wind energy is a rapidly growing industry in the United States, particularly on the Outer Continental Shelf along the Atlantic coast. As of 2019, the United States has had a goal to produce over 26,000 MW of offshore wind energy; Massachusetts has a target to produce 3,200 MW by 2035. The Massachusetts Wind Energy Area (MA WEA), located 20 miles south of Narraganset, MA, has been leased out by the Bureau of Ocean Energy Management (BOEM) to several proposed wind energy facilities, including what will be the first industrial-scale offshore wind energy facility in the United States. There have been several assessments in Europe and in the United States regarding the potential impacts of electric and magnetic fields (EMFs) from underground sea cables on marine species, citing the potential for EMFs to disorient sensitive species and disrupt their migration or foraging success. Generally, EMF risk assessments have determined impacts on marine animals to be negligible; however, studies on EMF impacts are still in the preliminary stage and have produced varied results. Current available research on the cumulative impacts of EMFs has shown some behavioral impacts to marine species and call for further experimental research on the subject. Like other electromagnetic-sensitive fish species, elasmobranchs (sharks, rays and skates) have shown little to no behavioral changes to EMFs emitted from individual offshore wind developments; however, EMF effects are species- and project-specific and behavioral effects have been shown to occur in the presence of highly-concentrated EMFs. In this literature synthesis, we conduct a preliminary evaluation of the potential cumulative impacts of EMFs on elasmobranchs known to occur in and near the MA WEA from several proposed offshore wind facilities, taking into consideration other anthropogenically-sourced EMFs that occur in the area. The evaluation provides an overview of elasmobranch species of concern that occur in the MA WEA and their known EMF-detection levels. We integrate this information to identify areas of influence for the species, incorporating relevant specifications of industry standard underground sea cables and other known EMFs of natural and anthropogenic origin. This evaluation is based on a review of published scientific literature and publicly available technological reports, including impact assessments conducted for established offshore wind facilities in Europe and proposed offshore wind facilities in the United States. We hypothesize that there may be some behavioral effects elicited by elasmobranchs once offshore wind development is complete in the MA WEA due to a higher concentration of EMFs produced

in a localized area. We also discuss how our conclusions could inform future experimental research on the effects of cumulative EMFs on marine animals and support additional regulatory guidelines for offshore wind development.

53: Keeping the lights on: first attempt at year-round nighttime ultraviolet illumination of wind turbines for deterring bats.

Presenter: Paul Cryan (U.S. Geological Survey, U.S.)
Authors: Paul Cryan (U.S. Geological Survey, U.S.), P. Marcos Gorresen (University of Hawaii at Hilo - Hawaii Cooperative Studies Unit, U.S.), Bethany Straw (National Renewable Energy Laboratory, U.S.)
Abstract: Wind operators currently lack device-based methods that prevent most bat fatalities at wind turbines. We developed a potential light-based method of dissuading bats from approaching wind turbines based on evidence that they visually perceive turbines from afar at night and approach to investigate. Here we present results of our attempt to splash dim, flickering, ultraviolet (UV) light across the monopoles and blades of two operational industrial-scale wind turbines at night while assessing whether the light was visible to humans, bats, birds, or insects. We magnetically attached 12 LED lights around the monopole of each turbine, 20m above the ground, pointing upward. Installation of each light system took less than a day using an aerial lift. We monitored UV light cast on the turbines with time-lapse landscape cameras and characterized night-flying animal presence and behaviors using thermal infrared surveillance cameras magnetically attached to the turbine monopoles. Results were mixed, but we substantially improved the technology as a result of this study. Electrical, timing, and camera systems installed easily, functioned well throughout the year, survived several extreme weather events, and generally required little maintenance. Our UV lights failed due to water incursion prior to the bat active season, so we could not test whether they prevented bats from approaching the turbines. However, field observation and time-lapse imagery clearly demonstrated that we successfully UV-lit the monopole, underside of the nacelle, and blades of the turbines at night. The UV illumination was invisible to humans and video revealed no clear indication that night-flying animals (including insects) were attracted to the lights. We are now sharing these improved methods to encourage further testing of whether dim UV illumination of wind turbines can prevent bat fatalities.

54: Movement patterns of migratory tree-roosting bats during autumn migration

Presenter: Erin Swerdfeger (University of Regina, Canada)
Authors: Erin Swerdfeger (University of Regina, Canada), Erin Baerwald (University of Northern British Columbia, Canada)
Abstract: As wind power generation capacity is proposed to dramatically increase across the Great Plains, there is some urgency to better understand landscape scale migration patterns of North American bats. Large numbers of bat fatalities recorded at wind energy facilities during autumn are contributing to likely population declines of hoary bats (*Lasiurus cinereus*), eastern red bats (*L. borealis*), and silver-haired bats (*Lasionycteris noctivagans*). One potential management solution is to incorporate known areas and patterns of high migratory bat activity in the early planning stages for siting wind energy facilities. Migrating bats have been shown to concentrate along select routes on the northwestern edge of the Great Plains. If this holds true in other areas, then at a broad scale, future wind energy facilities in areas with fewer available migrating bats are likely to be lower risk to bats.

Thus, we aimed to determine where bats move through southern Saskatchewan during autumn migration, when their risk of fatalities at wind energy facilities is greatest. Our second objective was to determine how close to the river bat activity is concentrated along major river corridors, which are included in Wind Turbine Avoidance Zones under Saskatchewan guidelines. We hypothesized that bats

follow defined landscape features that provide resources to migrating individuals, such as navigational guides, foraging opportunities, and roosting habitat. In the Great Plains, these may include landscape features such as ridge lines and river corridors. Our research approached this wind-wildlife challenge using bioacoustics. During the southern Saskatchewan migration season (July to September) of 2018 and 2019, we installed a set of detectors along 5 km transects perpendicular to four of the province's major rivers. Final results of general linear mixed models will be available by winter 2020. Preliminary results show that activity was generally higher in riparian areas and decreased with distance from rivers. This is consistent with access to resources such as roosting habitat and water being important in bat migration route selection. Sites located in riparian areas and the southeastern portion of the province contain more forested landscape than other sampling sites located in uplands and grassland ecoregions. This information can potentially be used across the North American Great Plains to inform wind power siting decisions on a broad scale and better plan future wind energy projects to enable increased capacity while maintaining biodiversity.

55: Hawaiian hoary bat (Lasiurus cinereus semotus) behavior at wind turbines on Maui

Presenter: P. Marcos Gorresen (Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, U.S.)
Authors: P. Marcos Gorresen (Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, U.S.), Paul Cryan (U.S. Geological Survey, Fort Collins Science Center, U.S.), Grace Tredinnick (Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, U.S.)
Abstract: Recent research has found hoary bats often forgo echolocation, or do not always vocalize in a way that is detectable with common acoustic monitoring methods. Silent flight behavior may be more prevalent in echolocating bats than previously appreciated and has implications for acoustic-triggered curtailment of turbine operation aimed at minimizing or avoiding fatalities. We monitored the endemic Hawaiian hoary bat (*Lasiurus cinereus semotus*) with both acoustic and visual (thermal videographic) methods at wind turbines on southern Maui Island, Hawai'i, between August and November 2018. We present results of the correspondence between acoustic and visual-based detection rates, as well as nightly patterns of activity and behavior in relation to wind speed, precipitation, and blade-movement transitions.

We visually and acoustically detected bats on less than half of the turbine-nights monitored, and detections with both methods tended to peak during the first third of the night, with events largely absent in the latter half of the night and no apparent seasonal trend towards earlier or later occurrence within nights. Visual bat detections were weakly but not significantly correlated at the timescale of nights, but were spatially correlated among individual turbines). We visually detected bats most frequently at relatively low wind speeds (median = 3.4 m/sec), but also sometimes at wind speeds over 8.5 m/sec. Generalized linear mixed model analysis confirmed that detection rates were negatively associated with wind speed and precipitation. We also found evidence that detection rates increased in association with frequent changes in the status of blade movement. Most visual observations involved bats flying to within about 15 m of the turbine nacelle, usually following an erratic flight path and often repeatedly approaching and circling the nacelle. We rarely detected echolocation calls indicative of active feeding. Hawaiian hoary bats were often acoustically active when present at the wind energy facility, but also seemed to exhibit the cryptic vocalization behavior noted in other settings. Acoustic detectors confirmed bat presence in about half of the turbine-nights for which we visually detected bats. However, vocalization was often not detected at finer time scales of sampling, such as hourly and 10-minute intervals, during which bats were visually observed. The frequent lack of acoustic detections within an appropriate response period for triggering turbine curtailment may have implications for the effectiveness of acoustic-informed 'smart curtailment'.

56: Behavioral patterns of bats at a wind turbine confirm seasonality of fatality risk

Presenter: Shifra Goldenberg (Smithsonian Conservation Biology Institute, U.S.)
Authors: Shifra Goldenberg (Smithsonian Conservation Biology Institute, U.S.), Paul Cryan (U.S. Geological Survey, U.S.), P. Marcos Gorresen (University of Hawaii at Hilo, U.S.), Lee Jay Fingersh (National Renewable Energy Laboratory, U.S.)
Abstract: Bat fatalities at wind energy facilities are predominantly comprised of migratory, tree-dependent species, but it is unclear why these bats are at higher risk. Factors influencing bat susceptibility to wind turbines might be revealed by temporal patterns in their behaviors around these dynamic landscape structures. In northern temperate zones fatalities occur mostly from July through October, but whether this reflects seasonally variable behaviors, passage of migrants, or some combination of factors remains unknown. In this study, we examined video imagery spanning one year in Colorado to characterize patterns of seasonal and nightly variability in bat behavior at a wind turbine. We detected bats on 178 of 306 nights representing approximately 3,800 hours of video and > 2,000 discrete bat events. We observed bats approaching the turbine throughout the night across all months during which bats were observed, with two distinct seasonal peaks of bat activity in July and September. Bats exhibited behaviors around the turbine that increased in both diversity and duration in July and September. The distinct seasonal peaks in bat events were reflected in turbine approach behaviors and chasing behavior. Many of the bat events involved multiple approaches to the turbine, including when bats were displaced through the air by moving blades. The seasonal and nightly patterns we observed were consistent with the possibility that wind turbines invoke investigative behaviors in bats in late summer and autumn, and that bats may return and fly close to wind turbines even after experiencing potentially disruptive stimuli like moving blades.

57: How low can you go? Optimizing curtailment on a regional scale to reduce bat fatalities and energy loss.

Presenter: Trevor Peterson (Stantec Consulting Services Inc., U.S.)
Authors: Trevor Peterson (Stantec Consulting Services Inc., U.S.), Adam Rusk (Stantec Consulting Services Inc., U.S.)
Abstract: Stantec's research since 2011 at two West Virginia wind farms has demonstrated that acoustic bat data recorded at nacelle height can be used to characterize conditions with high risk to bats and design smarter curtailment strategies that achieve target fatality reductions with substantially less energy loss. We will summarize recent reanalysis of these datasets conducted as part of U.S. Department of Energy-funded smart curtailment research, demonstrate how acoustic data can be used to optimize and evaluate curtailment, and extend these results to a national scale by comparing alternative pathways to reducing fatalities of hoary bats and federally listed *Myotis species* across the species' ranges. Managing risk of taking federally listed bat species remains a challenge for the wind industry and regulatory agencies alike. Although curtailment remains one of the most effective tools to reduce bat fatality rates, coarse understanding of the effect of wind speed and other variables on risk hampers the ability to use curtailment strategically by focusing only on conditions with high risk. Critically, curtailment will not be a useful tool to manage impacts to a widely ranging species such as hoary bats unless it is implemented broadly, which in turn requires greater flexibility in how curtailment plans are designed.

Our analysis of nacelle-height acoustic and fatality data demonstrates that the amount of bat activity exposed to turbine operation is a quantitative and meaningful metric of risk that is ideally suited for designing strategic curtailment programs. Absent such information, selecting a curtailment cut-in wind speed is analogous to setting an appropriate speed limit for a road without information on traffic

patterns, pedestrian activity, or road characteristics. Blanket curtailment can be effective, but is similar to a universal 45 MPH speed limit; too low for some situations and too high for others. Using our results from previous smart curtailment studies as a proof of concept, we will then extend the concept of strategic curtailment design to the national stage and use regional fatality patterns and installed wind capacity data to simulate cumulative energy loss for alternative curtailment strategies targeting 75% overall reduction in hoary bat fatality and avoidance of Indiana bat fatalities. This exercise demonstrates the substantial amount of lost potential energy generation that is at stake when considering curtailment on a broad scale and highlights the need to be more strategic about how agencies and the wind industry approach curtailment. Our presentation will therefore provide quantitative results from two case studies and explore the larger scale implications of these results for the viability of curtailment as an effective tool to manage risk to bats on a national level.

59: Modification of Eagle Search Methods with Consideration of Project Topography

Presenter: Marci Trana (Western Ecosystems Technology, Inc., U.S.)
Authors: Marci Trana (Western Ecosystems Technology, Inc., U.S.), Todd Mattson (Western Ecosystems Technology, Inc., U.S.), John Lombardi (Western Ecosystems Technology, Inc., U.S.), Nick O'Neil (Western Ecosystems Technology, Inc., U.S.)
Abstract: Eagle incidental take permits issued to wind farm operators require third-party post-construction monitoring for potential take. Recently, this monitoring has commonly involved a method of visually searching out from the base of a turbine for injured or dead eagles. This method has been highly effective in flat and open environments where large birds, such as eagles, can readily be seen from a distance. Additionally, it is a more cost-effective method than the traditional approach of walking spaced transects around turbines. Topography can sometimes constrain the viewshed from the base of a turbine. In looking at a project-specific case study, the complex topography of the Loess Hills region of the Midwest led to a highly reduced viewshed surrounding each turbine located at the Rock Creek Wind Energy Facility. At search locations, traditional scan methods provided 52% of the total searchable area to be viewed. By using a modified scan approach, where the observer stands partway across the scan plot to scan toward and away from the turbine, we were able to improve the viewshed to 89%. These improvements in viewshed resulted in an increased overall probability of detection (g) from 0.32 to 0.66. Going forward, monitoring for eagle fatalities as a condition of an incidental take permit requires a closer look at the particular constraints of each wind farm. If scan methods are modified to accommodate these conditions, measures of search effort can be maintained at a high level without the need to resort to more intensive walking transect-style methods.

60: The use of radar and observers: from strategic planning to mitigation

Presenter: Ricardo Tomé (STRIX – Environment and Innovation, Portugal)
Authors: Ricardo Tomé (STRIX – Environment and Innovation, Portugal), Alexandre Leitão (STRIX – Environment and Innovation, Portugal), Filipe Canário (STRIX – Environment and Innovation, Portugal), Nadine Pires (STRIX – Environment and Innovation, Portugal), Nuno Vieira (STRIX – Environment and Innovation, Portugal), Ricardo Oliveira (STRIX – Environment and Innovation, Portugal)
Abstract: Wind farms may impact negatively on birds, for instance causing mortality due to collisions with turbines. These impacts are highly site- and species-dependent and situations such as migratory flyways for soaring birds are typically associated to higher collision risk. Comprehensive data on local bird communities, their movement patterns and behaviors is therefore a requisite for a better evaluation of the risks associated to the construction of a wind farm and for designing and implementing potential mitigation or compensation measures that will deliver a no-net loss in biodiversity. Although such data is commonly obtained by using field observers the use of remote technologies like radar is

increasing. We discuss the usefulness of these two sources of ornithological data, its relative importance, possibilities of integration and interdependencies both in the strategic planning of wind energy developments and in operational mitigation of impacts, such as temporary shutdown of turbines. We address the main advantages and constraints of each methodological approach relative to e.g. needed manpower, detection capacity and efficiency, species identification, covered area and birds' flight height. Several theoretical and real scenarios will be discussed, considering variables like the scale, environment (offshore and onshore), topography and ecological complexity of the projects. We further discuss the cost-efficiency of the different solutions, as well as possibilities for future improvements.

61: Evaluating appropriate survey effort for vultures at an African savannah wind farm site

Presenter: David Wilson (The Biodiversity Consultancy, United Kingdom)
Authors: Dominic Kimani (Kipeto Energy PLC, Kenya), Mary Warui (Kipeto Energy PLC, Kenya), David Gitau (Kipeto Energy PLC, Kenya), Libby Hirshon (Biotherm Energy, South Africa), David Wilson (The Biodiversity Consultancy, United Kingdom), Leon Bennun (The Biodiversity Consultancy, United Kingdom)
Abstract: Pre-construction surveys at proposed wind farm sites allow evaluation of potential impact from the development, with minimum survey effort requirements specified in various guidance documents (e.g. 36 h per breeding/non-breeding season or 12 h per site per season). Here, we evaluate the effect of increasing survey effort on fatality estimates at a proposed wind farm site in an African savannah ecosystem. We focus on Rüppell's Vulture *Gyps rueppelli* and White-backed *Vulture G. africanus*, two critically endangered species that occur on site. The daily abundance of both species on site is highly variable, and strongly influenced by the presence of carrion. Between 2017 and 2019 we completed approximately monthly vantage point survey sessions at six sites with a consistent survey team, for over 2800 h of effort and observing over 2500 vultures during that time. We use those data to estimate cumulative passage rates for all observations and those at collision risk height over the full survey period. We then investigate how these measures would have differed if observations had followed guidance-recommended effort within this time range. We then use these measures to derive species-specific fatality estimates for the wind farm, and evaluate how closely the estimates after guidance-recommended survey effort match those from the much more extensive overall dataset. We then consider what levels of survey effort might be required to obtain reliable estimates of fatality rates for vultures and/or African savannah habitats.

62: Ecology of scour protection in offshore wind farms – biodiversity enhancement, ecosystem-services and options for eco-design from Europe

Presenter: Wouter Lengkeek (Bureau Waardenburg, Netherlands)
Authors: Wouter Lengkeek (Bureau Waardenburg, Netherlands), Karin Didderen (Bureau Waardenburg, Netherlands), Malenthe Teunis (Bureau Waardenburg, Netherlands), Tom van der Have (Bureau Waardenburg, Netherlands), Edwin Kardinaal (Bureau Waardenburg, Netherlands)
Abstract: The southern North Sea once harboured extensive hard substrate habitats, in the form of glacial rock and fluvial gravel deposits, course peat remnants and large areas with oyster reefs. Due to human interference, only the glacial rock and fluvial gravel bed habitats remains today, and the southern North Sea seabed consists almost entirely of sandy bottom. Offshore wind farms in the North Sea add artificial hard substrate (foundation and scour protection) to this soft sediment dominated ecosystem. The wind farms thereby increase habitat suitability for hard substrate associated species and communities occurring naturally in the North Sea. The European flat oyster (*Ostrea edulis*) for example is an endangered species and habitat (listed in the EU Habitats Directive, OSPAR or national red lists), which can benefit from hard substrates, to grow and thrive. In addition, Atlantic cod (*Gadus morhua*), an

ecological and commercially important fish species, uses gravel beds to forage and needs hiding space in large pores between rocks (or other structures) in their adult life stage. Based on existing monitoring data from current offshore wind farm scour protection, other artificial hard substrates and natural hard substrates from the North Sea, it is hypothesized that an optimized design of scour protection will enhance populations of ecological and commercially important species like flat oyster, Atlantic cod and enhance biodiversity in general, including policy-relevant species. We present results of ecological studies of species assemblages on scour protection in the North Sea, Europe, where we:

- Describe patterns of biodiversity and species abundance over time
- Derive design variables for bespoke and optimised designs
- Quantify effects of ecosystem services

Additionally, we discuss the options and needs for cost-effective monitoring and discuss the reduction or mitigation of negative impacts.

63: A Multi-Sensor Approach for Measuring Bird and Bat Collisions with Offshore Wind Turbines

Presenter: Jennifer Stucker (Western EcoSystems Technology Inc., U.S.)
Authors: Jennifer Stucker (Western EcoSystems Technology Inc., U.S.), Rhett Good (Western EcoSystems Technology Inc., U.S.)
Abstract: Offshore wind energy is well-established in Europe and is an emerging industry in the U.S. Understanding potential impacts to birds and bats is an important factor in the permitting of an offshore wind farm. Assessing such impacts is challenging given harsh offshore conditions and the inability to conduct standardized carcass searches similar to land-based turbines. Therefore, development of automated monitoring technologies is a key factor to advancing offshore wind energy. Automated monitoring systems could also identify the time of night when a bat fatality occurs which can inform more accurate smart curtailment systems for bats at land-based wind farms. WEST is leading the development of an automated, multi-sensor system for detecting and quantifying bird and bat collisions at offshore or land-based wind farms. In collaboration with TNO, NREL, and LEEDCo, WEST's project funded by the DOE will advance TNO's existing WT-Bird® system that has successfully detected large bird collisions during the daytime at an offshore wind farm in the Netherlands. The existing system includes acceleration sensors installed in turbine blades to detect collision impacts, and cameras installed at the base of the turbine to record collision events. The primary objective of the DOE-funded project will be to advance the WT-Bird® system to also detect smaller bird and bat collisions during both daytime and nighttime hours. Two major technological advancements resulting from the project include: 1) improving the sensitivity of acceleration sensors to detect small bird and bat collisions, and 2) integrating machine learning algorithms to process video data collected by the cameras to automatically identify and classify a bird or bat collision to guild.

The advanced WT-Bird® system will be engineered and initially tested on a stationary blade on the ground at TNO. When the new sensors have proven to detect smaller weighted objects, the full system will be installed and will undergo robust testing using artificial objects launched at a test turbine at NREL's National Wind Technology Center in Boulder, Colorado; machine learning will be integrated to automatically classify sizes of objects as small, medium, or large. Preliminary tests at TNO have shown conventional sensors' abilities to detect vibrational measurements from smaller objects weighing 7 grams (g) and 50g, equivalent to small birds/bats and medium-sized birds, respectively. Improved optical sensors will be further tested to detect smaller objects against operational noise of running turbines. Enhanced camera systems are also being evaluated for determining optimal resolution needs for high accuracy of machine learning classifications. A test plan for installing and initially validating the system at NREL is currently underway. Preliminary results of testing the advanced system will be shared at

NWCC. When the full system meets a set of test performance criteria at NREL, it will be installed and validated at a land-based wind turbine (planned for 2021) and offshore wind turbine (2022). This automated detection system will provide the wind industry with an advanced, science-based monitoring system for quantifying bird and bat impacts at offshore wind farms.

64: Relationship between Bat Fatality Rates and Turbine Size at Wind Farms across the Continental U.S. and Southern Canada

Presenter: Fawn Hornsby (West Inc., U.S.)
Authors: Fawn Hornsby (West Inc., U.S.), Wallace Erickson (West Inc., U.S.), Kevin Murray (West Inc., U.S.), Jared Studyvin (Western EcoSystems Technology Inc., U.S.), Christian Newman (EPRI, U.S.)
Abstract: Wind energy is one of the most rapidly-growing sources of renewable energy in North America. As the industry has grown, turbine size has increased. Wind turbines are responsible for a substantial level of bat fatalities in North America and there is concern that as larger turbines are built on the landscape the risk to bats may grow. Several independent researchers have documented an increase in bat fatalities per turbine with increasing turbine size. However, nearly all of these studies are over a decade old and do not include turbine sizes that are now commonly in use. We analyzed a dataset of 277 publically-available studies from 181 different wind energy facilities in the U.S. and Canada (1998 to 2018) to examine the relationship between turbine size characteristics (e.g. hub height, rotor-swept area, and capacity) and estimated bat fatalities. Turbines sizes included in the analysis range from 55 m to 120 m hub height, 22.0 m to 62.5 m blade length and 0.6 MW/turbine to 3.3 MW/turbine capacity. We generally found only weak correlations between bat fatality rates and turbine size variables. For example, Pearson's correlation coefficient for the number of bat fatalities/turbine/study period versus hub height (m) and RSA (m^2) were 0.033 and 0.237, respectively. Bat fatalities peaked at intermediate turbine sizes (i.e. hub heights of 80 m and RSA approaching 8,000 m^2) and decreased at larger turbine sizes. In addition, we found no fundamental differences between use of bat fatalities/turbine and bat fatalities/MW. The observed relationships of both of these bat fatality metrics to different turbine size variables were similar.

65: Emerging applications and trends related to remotely sensed imagery analysis for habitat and wildlife mapping in support of wind energy project development

Presenter: Ian Evans (DNV GL, Canada)
Authors: Ian Evans (DNV GL, Canada), Ashley Rieseberg (DNV GL, Canada), Francis Langelier (DNV GL, Canada)
Abstract: Habitat mapping and evaluating wildlife presence are important considerations in wind energy project development, often due to regulatory requirements mandating avoidance and/or mitigation of habitat loss and degradation resulting from project development. Avoidance of habitat during early-stage site selection is typically informed by generalized mapping of habitats and wildlife activity over large spatial extents, while later-stage siting of project infrastructure requires more detailed site-specific mapping of individual habitats and species presence. Regardless of the spatial extent or development stage, analysis of remotely sensed data from satellites, manned aircraft, or unmanned aerial vehicles (UAV) can play a pivotal role in developers' understanding of habitats and wildlife. In the case of early-stage site selection, reliable remotely sensed data can reduce regulatory challenges and avoid sunk costs by providing a more accurate understanding of current conditions of potential sites before investing significant money into a project. For later-stage infrastructure planning after a site has been selected, remotely sensed data can reduce or eliminate the need for expensive and time-consuming site surveys. This presentation provides an overview of the latest applications of and trends in remotely sensed imagery analysis and discusses how these emerging applications can be used to support wind project

siting and development while simultaneously minimizing the impact that these projects will have on wildlife and wildlife habitat. The presentation will include recommendations for obtaining agency buy-in on these new approaches, as well as discuss the limitations and challenges that necessitate the continued evolution of remote sensing. Applications that will be covered in this presentation include but are not limited to: (1) mapping bird abundance, (2) delineating wetlands in the Prairie Pothole region of North America, and (3) vegetation presence mapping and growth monitoring. The data sources and image classification techniques used in these applications are also discussed.

66: A test of weather and time-based smart curtailment for bat fatality reduction

Presenter: Paul Rabie (WEST, Inc., U.S.)
Authors: Paul Rabie (WEST, Inc., U.S.), Andrew Tredennick (WEST, Inc., U.S.), Nicole Kopysh (Pattern Energy Group, Canada)
Abstract Some Approaches to Accounting for Incidental Carcass Discoveries in Non-Monitored Years using the Evidence of Absence Model — OFR 2020-1027. Impact to bats is an enduring challenge for the wind power industry. The most reliable known measure to reduce bat fatality is curtailment of turbine operations below a threshold wind speed, but such “blanket curtailment” strategies are costly in terms of lost power production. Smart Curtailment (SC) refers to a range of strategies to implement curtailment only when risk to bats is high. Our understanding of risk to bats is imperfect; we assume that risk at most North American sites has a seasonal component that is moderated by weather conditions. Recorded times-of-collision between bats and wind turbines would be a direct measure of risk but are difficult to obtain. Consequently, bat acoustic activity – which can be gathered with to-the-second temporal resolution – is sometimes used as a proxy metric for risk.

The Henvey Inlet Wind Energy Center (HIWEC) project in Ontario (a partnership between the Nigig Power Corporation - a subsidiary of Henvey Inlet First Nation - and Pattern Canada) has a permit obligation to employ an SC strategy to reduce impacts to bats. The facility was completed in late 2019 so fatality data were not available at the time of SC algorithm development. We used site-specific bat activity and weather data from 2019 to design an SC algorithm that balanced energy production loss against projected risk reduction. The resulting algorithm triggers curtailment based on wind speed, date, and time of night during evening hours from June 1 through September 30. Temperature and spatial location were not sufficiently predictive for inclusion in the algorithm. Two assumptions underlying the algorithm at HIWEC are: 1) acoustic activity is a good proxy for bat risk, and 2) acoustic activity can be predicted based on time and weather. We designed a study to test these assumptions and assess the algorithm. Wind turbines at HIWEC were assigned to SC or control treatments (no curtailment; turbines blades feathered below cut-in speed). Acoustic bat activity data were collected at 14 turbines (split randomly between treatments).The accuracy of the algorithm will be evaluated by determining what the level of bat acoustic activity was during those periods of time in 2020 when the algorithm predicts risk to bats. This comparison evaluates the efficacy of the algorithm under the assumption that bat acoustic activity is a perfect indicator of risk to bats. Results are expected to show the potential for SC to meet bat conservation objectives while minimizing financial impacts to operators.

67: Automated measurements of bird movements in an offshore wind farm

Presenter: Abel Gyimesi (Bureau Waardenburg, Netherlands)
Authors: Abel Gyimesi (Bureau Waardenburg, Netherlands), Jacco Leemans (Bureau Waardenburg, Netherlands), Elisa Bravo Rebolledo (Bureau Waardenburg, Netherlands), Daniel Beuker (Bureau Waardenburg, Netherlands), Robert Jan Jonkvorst (Bureau Waardenburg, Netherlands), Rob van Bemmelen (Bureau Waardenburg, Netherlands), Robert Middelveld (Bureau Waardenburg,

Netherlands), Mark Collier (Bureau Waardenburg, Netherlands), Ruben Fijn (Bureau Waardenburg, Netherlands)
Abstract: The Dutch government targets to produce 16% of generated energy sustainably by 2023. Consequently, it has been agreed that an additional 3,450 MW offshore wind energy should be realized on top of the 1,000 MW that has been built already. In 2016, a five-year governmental ecological research program on offshore wind energy and wildlife interactions (Wozep) was launched to study the knowledge gaps in the ecological effects of offshore wind energy. As part of this program, the government intends to measure the intensity of local bird movements and of land bird migration over the sea. Therefore, a network of dedicated bird radars in offshore wind farms is planned to be developed. As a first step, in 2018 a dedicated bird radar system, consisting of a horizontal and vertical radar, was installed in the offshore wind farm Luchterduinen, to measure fluxes, avoidance behavior, as well as flight speed and altitudes of birds. To complement the radar observations with species information, we have been conducting visual observations locally in the wind farm. Based on the results of the first year of the study, the radar recorded an overall mean traffic rate of 36 bird tracks/km/hour, with a maximum of more than 3,000 tracks/km/hour during nights with autumn migration. Such exceptionally high fluxes of more than 500 bird tracks/km/hour were only recorded in 2% of all observation hours. During the field observations, 27 bird species were identified, also including migrating land birds but excluding night migrants. Based on the radar and field measurements, we could determine preliminary values for species-specific flight speeds and altitudes and avoidance rates for the meso- (within the wind farm among the turbines) and macro level (avoidance of the entire wind farm), all vital parameters for future collision rate modelling.

68: Landscape factors associated with fatalities of migratory tree-roosting bats at wind energy facilities in the midwestern and northeastern U.S.

Presenter: Kimberly Peters (DNV GL, U.S.)
Authors: Kimberly Peters (DNV GL, U.S.), Ian Evans (DNV GL, Canada), Elizabeth Traiger (DNV GL, United Kingdom), Jonathan Collins (DNV GL, United Kingdom), Cristen Mathews (DNV GL, U.S.), Amanda Klehr (DNV GL, U.S.)
Abstract: Improving our understanding of the large-scale ecological and geographical factors associated with potential collision risk to vulnerable bat species from wind energy development is of increasing interest to the wind industry and other stakeholders, as the identification of potentially higher or lower risk areas for bats can inform early-stage siting decisions and provide guidance for state or regional-level planning. However, few studies have been conducted to explore the relationships among landscape-level factors and risk to bats from wind energy operations. We examined fatality rates of three species of migratory tree-roosting bats commonly observed as fatalities at operational wind energy facilities - hoary bat (Lasiurus cinereus), silver-haired bat (Lasionycteris noctivagans), and eastern red bat (Lasiurus borealis) - in relation to landscape-scale features at varying scales to identify potential landscape-fatality associations. Fatality data acquired from the American Wind Wildlife Information Center (AWWIC) database represented 69 post-construction monitoring studies from 47 wind facilities in the midwestern and northeastern regions of the United States and included over 6,900 fatality records of the three target species. A multistage process including ensemble learning (random forests) and predictive modeling (generalized linear models) was used to explore associations between bat fatality rates and various landscape metrics calculated at the local, 2.5-kilometer (km), 5-km and 25-km scales. Final results indicated that landscape structure at the broadest scale examined was most strongly associated with fatality rates and revealed both similarities and differences between the two regions. In the midwestern region, a positive association between fatality rates and the proportion of developed land occurring within 25-km facility buffers was observed for all three of the target species, a pattern that

was also observed for hoary bat and silver-haired bat in the northeastern region. In the midwestern region, a negative relationship with road density was also observed at the 25-km scale, whereas at the turbine-area (i.e., local, facility-level) scale, fatality rates of the three target species tended to increase with road density. Hoary and eastern red bat fatality rates were also higher in the midwestern region when small disaggregated patches of open, non-cultivated habitat as opposed to clumped, larger patches occurred within and adjacent to facilities. In the northeastern region, fatality rates for hoary and eastern red bats appeared to also be driven by wetland structure; fatalities were highest when facilities were located in landscapes characterized by wetland complexes comprised of large and small wetland patches. The landscape patterns revealed in this study and others can better inform future research and siting decisions and feed into an adaptive learning process that will, over time, reduce uncertainty and lead to an improved understanding of factors associated with bat collision risk at wind facilities. It is anticipated that this enhanced understanding will further assist in the development of more accurate tools for assessing this risk and lead to the identification of scientifically informed options for avoiding, minimizing, and mitigating risk to bats.

73: Performance of the GenEst mortality estimator compared to the Huso and Shoenfeld estimators

Presenter: Manuela Huso (U.S. Geological Survey, U.S.)
Authors: Manuela Huso (U.S. Geological Survey, U.S.), Daniel Dalthorp (U.S. Geological Survey, U.S.), Paul Rabie (WEST, Inc., U.S.), Jared Studyvin (Western EcoSystems Technology Inc., U.S.), Daniel Riser-Espinoza (West Inc., U.S.)
Abstract: The two estimators of wildlife mortality at wind facilities that have seen the most widespread use in North America recently are the Huso estimator and Shoenfeld estimator (also called the Erickson estimator). GenEst is the newest statistical estimator to become available and was designed to improve upon the Huso and Shoenfeld estimators by generalizing the key assumptions in both, and to improve comparability among new PCM studies. In addition to relaxing some of the assumptions inherent to the Huso and Shoenfeld estimators, GenEst uses a novel approach to variance estimation through a parametric bootstrap. A practitioner's choice of estimator, however, should be based on its performance with respect to three important statistical properties: 1) bias—the tendency of an estimator to over- or under-estimate mortality, 2) precision—the ability of an estimator to constrain an estimate to a narrow range, and 3) confidence interval (CI) coverage—the probability that a CI with a specified level of confidence actually includes the true level of fatality. We conducted a simulation study to document the performance of GenEst relative to the Huso and Shoenfeld estimators. We took a simulation approach because simulation data allow comparison of fatality estimators under conditions where the "truth" is known and allow for large number of replications of each condition. The simulations cover a broad range of conditions from ranging from ideal to especially challenging. This range of conditions permits a comparison of the important differences among estimators and identification of the conditions under which they break down.

An important outcome from these simulations is the finding that the Huso-censored estimator (that requires inclusion in the fatality data of only those carcasses believed to have been killed in the interval preceding the search), and GenEst-est k (that estimates parameter k from trial data) are both unbiased (assuming perfect censoring for the former). Huso-not censored (in which no carcasses are excluded from the fatality data) is sometimes biased and is much more prone to under-coverage than Huso-censored. Although the Shoenfeld estimator was state-of-the-art when it was first introduced in 2004, it includes strong assumptions and our simulations show that it is biased and does not achieve nominal CI coverage under a variety of conditions. The practical implication for wind-power plant operators is that fatality estimates produced by GenEst should be comparable in magnitude to estimates produced by

Huso-censored. Practitioners transitioning from Shoenfeld to GenEst (or from Shoenfeld to Huso) should expect to see fatality estimates increase moderately due to the bias inherent in the Shoenfeld estimator. In practice, we do not know the true mortality in the field, nor any of the true parameter values for our search process. This simple fact emphasizes the value of an estimator—such as *GenEst*—that performs well under a wide variety of conditions.

74: Towards a Comprehensive View of Energy Development Impacts to Fish and Wildlife

Presenter: Mona Khalil (U.S. Geological Survey, U.S.)
Authors: Mona Khalil (U.S. Geological Survey, U.S.)
Abstract: The U.S. Geological Survey (USGS) provides scientific information to describe and understand the Earth's ecosystems and other natural processes. As the science agency of the U.S. Department of the Interior, USGS scientists work to deliver timely and relevant information on pressing resource management issues, including ways resource managers can balance natural resource conservation with an expanding energy generation infrastructure. USGS ecological research related to energy development has focused on delivering information to help resource managers and energy developers avoid, minimize, or mitigate the impacts of energy development on fish and wildlife. These studies improve our understanding of the specific risks energy generation facilities may pose to wildlife, provide methodologies to measure direct and indirect impacts to species and habitats, and leverage new understanding of species biology and ecology to inform solutions to minimize impacts through new technologies, management and mitigation strategies. We synthesize recent USGS research related to wind energy development and wildlife conservation, and place it within the larger context of research on impacts to wildlife and ecosystems from other energy generation sources and anthropogenic factors. We also describe new interdisciplinary efforts within the USGS and with external research partners that incorporate science on wildlife impacts from climate change. This integration of disciplines and current science can provide regulatory agencies and wind energy development stakeholders with an additional perspective to plan and manage our Nation's need for energy.

75: Estimating bat fatality at a Texas wind energy facility: Implications transcending the United States-Mexico border

Presenter: Sara P. Weaver (Bowman Consulting Group, U.S.)
Authors: Sara P. Weaver (Bowman Consulting Group, U.S.), Amanda Jones (Sandia National Laboratories, U.S.), Cris D. Hein (National Renewable Energy Laboratory, U.S.), Ivan Castro-Arellano (Texas State University, U.S.)
Abstract: Despite emphasis on understanding and reducing impacts to bats from wind energy, few data are available for the Southwest region of the United States and northern Mexico, which have high bat diversity and are areas of expanding wind energy deployment. Publicly available studies estimating bat fatality rates at wind energy facilities in North America mostly come from the Midwest and Northeast United States and Canada. Because species composition and fatality patterns vary among regions, cumulative continental impacts and continental patterns of fatality cannot be assessed and appropriate regional strategies to reduce impact cannot be selected without data from all regions. Here we provide estimates of bat fatality from a wind energy facility in southernmost Texas, thus providing insight on potential impacts of wind turbines on bats in northern Mexico given the shared species composition along the border region. We conducted a full year (March 2017–March 2018) of post construction fatality monitoring by searching 100 wind turbines in a 510-megawatt wind energy facility in Starr County, Texas, near the U.S.-Mexico border, and used GenEst (Generalized Mortality Estimator) to estimate bat fatality corrected for searcher efficiency, carcass removal, and density-weighted proportion of area searched. We found 205 bats comprising eight species during standardized searches, the

majority of which were Brazilian free-tailed bats (*Tadarida brasiliensis*, 78%) followed by northern yellow bats (*Lasiurus intermedius*, 11%). The estimated annual bat fatality was highest for Brazilian free-tailed bats at 6,288 bats/year (95% CI: 4,438–11,610) and northern yellow bats at 1,103 bats/year (95% CI: 552–2,154). The corrected fatality estimates were 16 bats/megawatt/year (95% confidence interval [CI]: 12–30 bats/megawatt/year) across all species. South Texas shares similarities in species composition, climate, and habitat with northern Mexico. Therefore, patterns of fatality at our site may be representative of those at wind energy facilities in the northern Mexico states of Tamaulipas (which borders Starr County to the south), Nuevo Leon, and Coahuila.

77: Situational Performance of Mortality Estimators

Presenter: Andrew Ryckman (Natural Resource Solutions Inc., Canada)
Authors: Andrew Ryckman (Natural Resource Solutions Inc., Canada), Charlotte Teat (Natural Resource Solutions Inc., Canada), Christy Humphrey (Natural Resource Solutions Inc., Canada), Lillian Knopf (Natural Resource Solutions Inc., Canada)
Abstract: In order to adequately assess the potential ecological effects of a wind energy facility on birds and bats, it is important to understand the abilities and limitations of the chosen mortality estimator. Although several studies have compared the relative performance of different mortality estimators, few, if any, have used real mortality data to assess how the site-specific variability in estimator trials may influence the results, overall performance, and ultimate usefulness of different potential mortality estimators. This study has examined the mortality monitoring results at sixteen operational wind facilities in Canada that each meet one of eight unique combinations of three common estimator variables, searcher efficiency (SE), carcass persistence (CP), and proportion of the area searched (PS) (e.g. high SE, high CP, high PS; low SE, high CP, low PS, etc.) to evaluate the relative performance of mortality estimators under site-specific conditions. In this study, mortality estimates were calculated using the Huso and GenEst mortality estimators, as well as a common estimator in Canada, regularly called the MNRF estimator. The purpose of this study is to examine the relative performance of different mortality estimators under different conditions to inform selection of an appropriate estimator under known, or suspected, conditions (e.g. areas of low CP). This presentation outlines the findings of the comparative analysis, including an overview of how each estimator performed under specific site-specific conditions, relative to the other estimators, and a comparison of how the known bias of each estimator may have contributed to its performance under different conditions.

79: A machine learning based intelligent thermal camera vision system for detecting, identifying, and tracking biological targets in and around wind turbines

Presenter: John Yarbrough (National Renewable Energy Laboratory, U.S.)
Authors: John Yarbrough (National Renewable Energy Laboratory, U.S.), Isabelle Cunitz (National Renewable Energy Laboratory, U.S.), Paul Cryan (U.S. Geological Survey, U.S.), Michael Lawson (National Renewable Energy Laboratory, U.S.), Bethany Straw (U.S. Geological Survey, U.S.), Cris D. Hein (National Renewable Energy Laboratory, U.S.)
Abstract: Bats are among the most vulnerable to impacts from wind energy development, with mortality at wind turbines estimated in the hundreds of thousands annually in North America. To develop effective solutions, it is crucial to understand not only the magnitude of impact (e.g., estimated rate of mortality), but the behavioral traits of bats and external drivers that can be most closely associated with risk. Bats are notoriously difficult to study, therefore, identifying specific behavioral trends and the precise environmental conditions at the time of collision requires a monitoring solution that can reliably collect relevant data. To date, thermal infrared video surveillance has been extensively applied to study bats and has proven to be a powerful yet cumbersome tool. Current analytical

approaches are time consuming because data processing has not been fully automated. In the past, steps have been taken to record avian and bat activity in conjunction with complicated image processing techniques that separate species from other moving objects within the field of view (i.e. clouds and portions of the wind turbine). Once the videos are collected, the post-processing does not allow real time monitoring and identification, leading to a delay in both studying the behavior of these species and determining the effectiveness of any impact reduction strategy being studied. Moreover, object identification capability is lacking, thus limiting the usefulness of video data. To resolve these issues, we are using open source computer vision and machine learning techniques allowing for automatic detection of objects in real-time with the ability to correlate these objects with environmental variables and recording the flight paths of each object. The code has gone through five rounds of development with images used to train the models. This advancement allows for automated real-time data collection, identification and tracking, thereby eliminating the need for long and tedious post-analysis processing of the videos. We will discuss the two open source and publicly available machine learning models developed within this scope of this work: 1) a binary model with a 99.68% accuracy in identifying the difference between an object and an empty scene, including wind turbine and clouds; and 2) a multiple classification model with the capability of identifying the type of object detected (bats (72% accuracy), birds (81% accuracy), insects (55% accuracy) and empty scenes (98% accuracy)).

80: Midwest Landscape Initiative Wind Working Group – Updates on Key Action Plan Activities and Overall Status / Coordination

Presenter: Scott Larsen (U.S. Fish and Wildlife Service, U.S.)
Authors: Hilary Morey (South Dakota Game, Fish and Parks, U.S.), Scott Larsen (U.S. Fish and Wildlife Service, U.S.), Kelley Myers (U.S. Fish and Wildlife Service, U.S.)
Abstract: The Midwest Landscape Initiative (MLI) created the Wind Working Group (WWG) to explore shared conservation priorities among the states of the Midwest Association of Fish and Wildlife Agencies (MAFWA) and the U.S. Fish and Wildlife Service (FWS). In identifying the need for the WWG, the MLI Steering Committee identified initial goals to enhance coordination and collaboration to avoid, minimize, or offset the direct and indirect negative impacts of wind power generation on wildlife and the surrounding environment. First convened in the fall of 2019, the WWG is a government-only "safe space" for these state and federal agencies with management responsibility for fish and wildlife.
With members comprised from the FWS, USGS, MAFWA and state natural resource agencies across 13 states of the Midwest, the WWG represents government priorities and interests across state and federal agencies. The structured and collaborative effort has become a model for how strong government agency coordination can serve as a strategic foundation for eventual interface with the sector.
The Wind Working Group (WWG) is excited to share additional background about the WWG's formulation, updates on the WWG's Action Plan progress, and discuss evolving priorities or potential findings from Action Plan activities. The outcomes of the WWG improve consistency across Midwest natural resource agencies to lessen wind turbine impacts to wildlife while also supporting more effective siting for wind development projects. There may be implications drawn beyond the Midwest region as well.

81: Hawaii Wind HCPs and the Hawaiian Hoary Bat: Lessons Learned Applicable to Other Tree-Roosting Bat Species

Presenter: Alicia Oller (Tetra Tech, Inc., U.S.)
Authors: Alicia Oller (Tetra Tech, Inc., U.S.)
Abstract: Habitat Conservation Plans (HCPs) associated with the issuance of incidental take permits (ITPs) for wind energy facilities in Hawaii have evolved since the first wind ITP was issued in 2006. In

addition to the federal ITP process with U.S. Fish and Wildlife Service, the State of Hawaii has an incidental take license (ITL) process with the Hawaii Department of Land and Natural Resources. Development of the HCP is a joint state and federal process. Eight wind-related HCPs and ITPs/ITLs have been approved and others are in process. These wind HCPs have included from three to eight covered species, with the Hawaiian hoary bat (*Lasiurus cinereus semotus*) being a focal species across all HCPs. The Hawaiian hoary bat is listed as endangered by the federal Endangered Species Act (ESA) and State of Hawaii Chapter 195D, Hawaii Revised Statutes. The species was listed primarily due to lack of information about the species and presumed habitat loss. The Hawaiian hoary bat is the only native land mammal present in the Hawaiian archipelago; it is most closely related to the hoary bat (*Aeorestes cinereus*), which occurs across much of North and South America. Although recent studies and ongoing research have shown that bats have a wide distribution across the Hawaiian Islands, a population estimate, life span, and limiting factors for the species are generally not known. Because of knowledge gaps in the biology of the species, developing take estimates and appropriate mitigation programs has posed challenges. As with wind HCPs for projects in other states, the processes have evolved and become more complex for: estimating the level of take, identifying appropriate avoidance and minimization measures, and developing mitigation and adaptive management programs. As part of the mitigation programs, several Hawaii wind HCPs have funded research targeted to learning more about the distribution, core use areas, diet, and other limiting factors of the Hawaiian hoary bat.

The recent evidence of decline in the hoary bat and potentially other tree-roosting bat species has become a focal issue for the wind industry when developing and operating wind projects. As concerns increase regarding impacts from wind energy on tree-roosting bat species, the permitting experience with the Hawaiian hoary bat as well as its similar biology provide valuable insight to navigating similar issues and facilitating the ITP process should the hoary bat be listed. Lessons learned from the development and implementation of multiple wind HCPs for Hawaiian hoary bats may include innovative avoidance and minimization measures, results from recent research, approaches to identifying creative mitigation programs, collaboration between multiple project owners/operators on various issues, navigating community challenges, and identifying novel monitoring and adaptive management programs.

82: Demographic impact of avian fatalities at wind energy facilities

Presenter: Tara Conkling (U.S. Geological Survey, U.S.)
Authors: Tara Conkling (U.S. Geological Survey, U.S.), Hannah Vander Zanden (University of Florida, U.S.), Jay Diffendorfer (U.S. Geological Survey, U.S.), Adam Duerr (Conservation Science Global, U.S.), Scott Loss (Oklahoma State University, U.S.), David Nelson (University of Maryland, U.S.), Julie Yee (U.S. Geological Survey, U.S.), Todd Katzner (U.S. Geological Survey, U.S.)
Abstract: Growth of wind energy extraction has created concerns regarding potential environmental impacts, such as for birds. However, although surveys at wind facilities are common, there is limited research examining the effects of wind energy derived wildlife fatalities on avian populations. We characterized the geographic origin of priority species killed at wind facilities in California, used these data to build species- and region-specific demographic models to assess vulnerability to wind energy development for each of these region-specific avian populations, and identified taxonomic or ecological correlates of that vulnerability. Of the 13 species we considered, preliminary analyses suggested vulnerability from wind energy fatalities of six species, for either local or both local and non-local populations. The other seven species were unlikely to be vulnerable to fatalities from wind energy. All but one vulnerable species were either residents or partial migrants, suggesting that species with the potential for year-round exposure may have greater demographic sensitivity to fatalities. Additionally,

the size of the potentially affected subpopulation provided more information about vulnerability than did the overall continental population size. In general, when the potentially affected subpopulation was small or geographically restricted, vulnerability was high. Our results highlight the species- and region-specific nature of the demographic patterns in vulnerability of these populations. They also illustrate the importance of obtaining baseline demographic data for species that occur near wind energy facilities and of estimating the region of origin of birds killed at those facilities. Doing so is a critical scientific component of risk assessment at wind energy facilities.

83: Going DARC for Bats

Presenter: Christine Sutter (Natural Power, U.S.)
Authors: Christine Sutter (Natural Power, U.S.)
Abstract: Smart curtailment builds on the well-established relationship between low blade RPM (<2) and lower fatality rates (Fieldler 2004). Achieving low RPMs requires pitching the blades out of the wind (curtailing), which precludes energy generation. Wind farm operators cite the loss of energy yield and revenue as the primary reason for not implementing standard curtailment regimes. DOE currently is funding several Bat Smart Curtailment (BSC) studies evaluating the effectiveness of various approached to reduce bat fatalities and minimize power loss. Natural Power has built a consortium of funders and collaborators (DOE, WWRF, Alliant Energy) to evaluate a detection and active response curtailment (DARC) strategy at Alliant's English Farms wind energy center (170 MW) in Iowa. This site is within the range of the Indiana and Northern long-eared bat and Northern long-eared bats were acoustically detected at the site during pre-construction studies. The site currently operates under a USFWS Technical Assistance Letter (TAL) conditions of 6.9m/s during the peak season of risk (Aug-Oct).
The purpose of the study is to assess if the DARC smart curtailment system significantly reduces bat fatalities while minimizing power production losses relative to blanket curtailment. Additionally, the fatality rates between 6.9 m/s BSC and 6.9 m/s blanket will be compared to evaluate whether DARC can provide an alternative to the most common TAL conditions. We present the initial results from the 2020 field study, including fatality rates per treatment group and relative effect on annual energy production across the three operational regimes: normal operation (curtail below 3m/s), 6.9 m/s blanket curtailment, and 6.9m/s DARC curtailment.

84: Monitoring Bat Activities at a Large Wind Farm Using an X-Band Radar and Infrared Cameras

Presenter: Jian Teng (University of Iowa, U.S.)
Authors: Jian Teng (University of Iowa, U.S.), Harrison Whitlow (University of Iowa, U.S.), James Niemeier (University of Iowa, U.S.), Jesse Leckband (MidAmerican Energy Company, U.S.), Anton Kruger (University of Iowa, U.S.), Corey Markfort (University of Iowa, U.S.)
Abstract: Wind energy is one of the fastest growing renewable energy sources. However, bat fatalities associated with wind power generation is a rising concern. In order to study the interaction of bats with wind turbines and to investigate the feasibility of using remote sensing tools for bat detection at a large wind farm, we conducted a multi-instrument bat detection experiment during the bat fall migration period within a wind farm in Iowa. An X-band polarimetric Doppler radar was deployed to scan the entire wind farm and the surrounding area up to 16 km. Two turbines within the farm were equipped with eight infrared (IR) cameras. Each instrumented turbine had four upward-looking cameras recorded bats flying near the wind turbine rotor, and the downward-looking cameras observe bats on the ground after impact with the turbine. Biometricians conducted regular bat carcass surveys at each turbine of the wind farm. The wind turbines' operating conditions and local weather conditions were also recorded. We present results from tests designed to explore the potential of X-band radar for the detection of bat activity at a wind farm scale using change in radar reflectivity and Doppler velocity

information. The radar results are compared with IR video and bat carcass survey data at the turbine scale. Videos from IR cameras were used to train a deep neural network to aid bat detection. The results will be used to develop strategies for mitigating wind farm impacts on bats.

86: A framework for predicting migratory behavior and wind-development impacts: Uniting morphological and life-history characteristics with distribution-based migration models

Presenter: Caitlin Campbell (University of Florida, U.S.)
Authors: Caitlin Campbell (University of Florida, U.S.), Hannah Vander Zanden (University of Florida, U.S.)
Abstract: As migratory organisms are increasingly affected by human impacts worldwide, including wind development, there is a growing need to understand which organisms migrate seasonally and between which habitats. However, migratory strategy and linkages are poorly understood for many taxa, due in large part to a paucity of recapture studies and the availability of geographic tracking technologies. We present a framework for characterizing the presence and type(s) of migratory behavior using species occurrence data, and identifying the morphological and life-history characteristics that predict migratory strategy. We will apply this framework initially to all species of North American bats. Using widely-available and publicly-generated distribution data, we will create seasonally-dynamic species distribution models; then, apply a suite of metrics to characterize the migratory strategy (presence, degree, and distance/direction of aggregated seasonal movements) of the focal species. These characterizations will be united with a database of individual- and species-level morphological and life-history characteristics to test which best predict migratory strategy. We will generate this database using tens of thousands of digitized museum records and existing repositories containing life-history strategies and migratory characteristics. Our approach builds on current knowledge of bat migration by quantitatively describing species-level seasonal shifts and incorporating individual-level variation across morphological characteristics. Additionally, this approach can be applied to all species for which even limited information exists, and is not limited to relatively well-studied species. We hope that this framework could eventually be united with information on turbine siting and mortality information to tease out the complex relationships between seasonal migrations and why turbine mortalities disproportionately affect some species of migratory organisms.

87: Nightly, Seasonal, And Annual Patterns Of Hawaiian Hoary Bat Activity From Bat Acoustic Monitoring At Wind Farms In Hawai'i

Presenter: Matt Stelmach (Tetra Tech, U.S.)
Authors: Matt Stelmach (Tetra Tech, U.S.), Christopher Todd (Tetra Tech, U.S.), Nathan Schwab (Tetra Tech, U.S.)
Abstract: Performing bat acoustic monitoring at Hawaiian wind farms provides important information about Hawaiian hoary bat activity patterns, which may provide insight into the risk drivers for bats from wind farm operation. The Hawaiian hoary bat is protected under the Endangered Species Act of 1973, which means the Habitat Conservation Plan (HCP) for each wind farm in Hawai'i must consider incidental take for this species. All wind energy HCPs in Hawai'i include acoustic monitoring for Hawaiian hoary bats. We compiled data covering five Hawaiian wind farms that resulted in a data set of over 20,000 calls summarized over 13 years (2006-2019) and five sites (consisting of over 40 site-years). This data set has provided insights into bat activity, as well as the limitations of acoustic data. We examined the seasonal, annual, and nightly trends with covariates for bat acoustic activity. The seasonal increase in Hawaiian hoary bat acoustic activity in August and September correlates strongly with observed fatalities. The acoustic activity rates vary strongly from year to year, making trend analysis challenging. Nightly acoustic activity is concentrated in the first six hours of the night, although the timing and

intensity of the peak varies from site to site. For calls with wind speed records, three patterns emerge: acoustic activity is negatively correlated with wind speed, many more calls are recorded at low wind speed, and wind speed does not predict all bat activity. Acoustic data has inherent limitations when used to understand the covariates associated with fatalities. Acoustic detectors only detect bats that echolocate within range of detectors and habitat can influence both behavior and detectability, which may bias acoustic sampling. Bat behavior and detectability can also change in response to ephemeral environmental conditions such as: rain, wind speed, and insect abundance. These underlying sources of variability of the acoustic data make pattern detection a challenge. Finally, the timing of fatalities is typically only known within a few hours, which means many prior conditions (wind speed, temperature, barometric pressure, or others) that may or may not be important predictors of fatality must be included in the analysis, which can mask the specifics at the time of collision. This analysis illustrates the strengths and weaknesses of acoustic data collection, with applications for future wind farm monitoring, minimization strategies, and general bat research.

89: 3-D offshore seabird observations in the Humboldt, California call area

Presenter: Shari Matzner (Pacific Northwest National Laboratory, U.S.)
Authors: Shari Matzner (Pacific Northwest National Laboratory, U.S.), Ryan Hull (Pacific Northwest National Laboratory, U.S.), Thomas Warfel (Pacific Northwest National Laboratory, U.S.), Nolann Williams (Pacific Northwest National Laboratory, U.S.), Alicia Gorton (Pacific Northwest National Laboratory, U.S.), Sharon Kramer (H.T. Harvey & Associates, U.S.), Scott Terrill (H.T. Harvey & Associates, U.S.), David Ainley (H.T. Harvey & Associates, U.S.)
Abstract: The ThermalTracker-3D avian remote sensing system is being integrated with a Wind Sentinel buoy to record seabird flight behavior in conjunction with wind energy resource characterization. The integrated system will be deployed 25 nautical miles off the California coast in BOEM’s Humboldt call area. The purpose is twofold: 1) test the operation of the ThermalTracker-3D system on a floating platform, and 2) collect detailed baseline seabird data, including nocturnal activity. BOEM is preparing to lease areas for offshore wind development off the California coast and has deployed two Wind Sentinel buoys, in collaboration with DOE and PNNL. The buoys collect vital wind profile and other oceanographic data. Integrating the ThermalTracker-3D system with the buoy makes it possible to collect seabird activity data correlated with wind speed and direction and other environmental conditions. Preliminary data from the deployment is presented.
Research setting. The research setting is a near-shore marine environment in the Pacific Northwest and BOEM’s Humboldt call area 25 nautical miles off the California coast. Near-shore validation will take place Oct 2020 through March 2021. Offshore deployment is planned to begin April 2021 and will last for six months. The location is in the California Current region where the diverse species composition includes albatrosses, shearwaters and peterels.
Methodology. The ThermalTracker-3D thermal stereovision system was integrated with a Wind Sentinel buoy to automatically record seabird flight tracks in varying wind conditions. The 3D flight tracks provide height above the sea surface and direction of flight. The track data can be used to calculate flux in the rotor-swept zone for collision risk modeling. During the deployment, field ecologists will make two separate trips to observe seabird activity at the buoy location to validate the ThermalTracker data and to provide ground truth for species identification. Throughout the deployment data was transmitted to shore daily to monitor the system’s operational status and to provide a summary of observed seabird activity.
Results. The ThermalTracker-3D system was validated on land in 2019 at NREL’s National Wind Technology Center using a GPS-equipped unmanned aerial system. Flight height estimates from the system were within ±10 m of the GPS-derived flight heights for 90% of data points and within ±5 m on

average (Matzner et al. 2020). Preliminary results from the buoy integration and near-shore validation will include densities and flight heights of seabirds as well as data on system performance, e.g., uptime and motion effects.
Management implications: The ability to collect baseline data on seabird activity correlated with wind speed and direction at remote offshore locations will provide information on seabirds that informs offshore wind siting decisions and improves understanding of the potential vulnerability of sensitive seabird populations to wind projects.

90: Fatality minimization targets for hoary bats assuming capacity for compensatory growth

Presenter: Nicholas Friedenberg (Western EcoSystems Technology Inc., U.S.)
Authors: Nicholas Friedenberg (Western EcoSystems Technology Inc., U.S.), Winifred Frick (bat conservation international, U.S.), Christian Newman (EPRI, U.S.)
Abstract Fatalities at wind farms may pose significant risk to the hoary bat population in Canada and the United States. Regulatory protection of the species would have pervasive effects on wind energy generation and development. Previous modeling sought fatality minimization targets necessary to manage the risk of hoary bat decline or extinction in light of future wind energy build-out. The population model used was intentionally conservative given large and fundamental gaps in our knowledge about hoary bat population size and growth. Here, we used a less sensitive model with compensatory population growth to assess how its increased stability affected guidance on the reduction in per-MW fatalities necessary to manage decline and extinction risk.

Maximum population growth rate was taken to be 1.18, the maximum among opinions in a previous expert elicitation (Frick et al. 2017). We assumed abundance was regulated by contest competition. The range of likely abundance produced by the elicitation, 1 to 10 million, was taken to represent possible equilibrium population sizes in the absence of wind fatality. Future wind energy build-out was assumed to follow the scenario of the 2015 Wind Vision report or a lower, market-based projection by the EIA. Monte Carlo simulation of population trajectories through 2050 were used to find the level of fatality reduction necessary to achieve less than a 50% chance of a 50% decline or a 1% chance of extinction.
As expected, the introduction of compensatory growth made the simulated hoary bat population more robust to wind fatalities and lowered the fatality reduction necessary to manage risk. For instance, in the conservative model a 70% reduction in hoary bat fatalities was sufficient to manage decline risk if a density-independent population had over 9 million individuals. With compensatory growth, that abundance threshold fell to about 2 million. Extinction risk would be managed in a population of less than 1 million hoary bats, versus about 2 million in the absence of compensatory growth.
It is significant that compensatory dynamics could make the hoary bat population more robust to wind energy build-out. However, it is also important to note: first, that there is no specific evidence for compensatory dynamics in hoary bats, and second, that including the capacity for compensatory dynamics did not change the basic assessment that risks could be present and depend fundamentally on population size. It is encouraging that both the compensatory model and its more conservative counterpart suggested that observed reductions in fatality rate, including those measured using deterrents, are sufficient to prevent extinction over much of the range of what is considered likely abundance.

91: Assessment of trends in bat fatality estimates at wind energy facilities

Presenter: Kristen Nasman (Western Ecosystems Technology, Inc., U.S.)

Authors: Kristen Nasman (Western Ecosystems Technology, Inc., U.S.), Kimberly Bay (Western EcoSystems Technology, Inc. (WEST), U.S.), Leigh Ann Starcevich (Western EcoSystems Technology, Inc. (WEST), U.S.)
Abstract: Temporal changes in bat fatality rates at wind energy facilities were evaluated using publicly available data from 53 wind energy facilities across the United States. In this analysis, we evaluated the relationship between bat fatalities rates and age of facilities and the trend in bat fatality rates from 1999 to 2019 using the available data. Environmental covariates were included in the analysis so the effect of facility age and year on bat fatality rates could be evaluated after accounting for the relationship with environmental variables. Environmental variables hypothesized to influence bat behavior and biology were considered and included weather and habitat covariates. In addition, the effect of neighboring facilities on bat fatality rates were also considered. Management of bat populations is not effective without accurate estimates of bat fatality rates, and changes in bat fatality rates based on age of facility does not provide an accurate assessment of how local bat populations are being impacted when only a single year of study is conducted. Additionally, understanding the relationship between environmental factors and bat fatalities may help to assess risk for future facilities.

92: Factors that influence the efficacy of operational minimization revealed by quantitative meta-analysis

Presenter: Michael Whitby (bat conservation international, U.S.)
Authors: Michael Whitby (bat conservation international, U.S.), Michael Schirmacher (bat conservation international, U.S.), Manuela Huso (U.S. Geological Survey, U.S.), Winifred Frick (bat conservation international, U.S.)
Abstract: Operational minimization, sometimes referred to as curtailment, is promoted as a way to significantly reduce bat fatalities at wind energy facilities. In 2013, Arnett et al. conducted a narrative synthesis of 10 operational minimization studies. They concluded that "…increasing cut-in speed between 1.5 and 3.0 m/s or feathering blades and slowing rotor speed up to the turbine manufacturer's cut-in speed yields substantial reductions in fatality of bats." Since Arnett et al.'s review, interest in understanding the factors that influence the efficacy of operational minimization has increased. However, comparing the reported effects of operational minimization across studies is made difficult by the numerous factors that vary between studies (e.g., turbine makes/models, control conditions, treatment conditions, decision frameworks, and study design).

While stark differences among study characteristics make it difficult to compare these studies directly, quantitative meta-analysis can account for these elements and elucidate the overall effect of operational minimization under given conditions. Quantitative meta-analysis combines the described effects and associated uncertainty of multiple studies through a measure of "effect size" (and associated uncertainty) that places results from all studies on the same scale. The accumulation of evidence from multiple studies (even those with low statistical power) is used to estimate the expected magnitudes of treatment effects and whether they vary predictably with certain factors (e.g., turbine characteristics). We used data from four facilities (six years) described in Arnett et al. 2013 augmented by data from an additional four wind facilities across nine different years. All studies provided an estimate of bat fatality (and confidence interval or standard error) at normally operating turbines and turbines with an increased cut-in speed during the same year. We used meta-analysis to quantify the efficacy of operational minimization across studies. We followed with meta-regression to describe how site-specific conditions influence operational minimization efficacy. We examine the effect of cut-in speed, geography, and study design (e.g., blocking factors, plot size) on the results. We also examine the species-specific efficacy of operational minimization for hoary bats (*Lasiurus cinereus*), eastern red bats

(*Lasiurus borealis*), and silver-haired bats (*Lasionycteris noctivagans*). Our preliminary results describe the effectiveness of curtailment as a percent reduction in fatality rates between curtailed and normally operating turbines. By describing the efficacy of specific operational minimization strategies, operators can choose the most appropriate and cost-effective measure for their facilities. Additionally, our findings provide a framework to compare operational minimization to other minimization techniques (e.g., bat deterrents).

93: Eastern red bat (Lasiurus borealis) and hoary bat (Lasiurus cinereus) foraging habits in an agricultural landscape

Presenter: Timothy Sichmeller (Western EcoSystems Technology, Inc. (WEST), U.S.)
Authors: Timothy Sichmeller (Western EcoSystems Technology, Inc. (WEST), U.S.), Kimberly Bay (Western EcoSystems Technology, Inc. (WEST), U.S.), Mandy Kauffman (Western EcoSystems Technology, Inc. (WEST), U.S.)
Abstract: Migratory tree bats comprise the majority of fatalities at wind turbines in the fall migration season. However, in Iowa, tree bat fatalities have been found at several wind facilities during the summer maternity season. From 2018 to 2019, WEST biologists conducted foraging telemetry on *Lasiurid* bats in central Iowa to examine summer and fall landscape use by tree bats in areas near wind turbines with limited forested habitat. A series of multi-azimuth triangulations were used to estimate the location of each bat as it foraged throughout the night. WEST obtained foraging data on eastern red bats (*Lasiurus borealis)*and hoary bats (*L. cinereus*).Eastern red bats exhibited notable intraspecific variation in home foraging range, but were larger on average (521.5 ha) than in similar studies and traveled greater maximum distances from their roosts (0.9 – 6.5 km). Several eastern red bats roosted in standalone trees in non-forested habitat types (agricultural land, residential areas) and foraged heavily in relatively open areas. Few data exist that describe foraging behavior of hoary bats. The hoary bats in this study had a larger total and core foraging range (9,482.5 ha and 1,113.3 ha, respectively), and foraged more extensively over agricultural land away from forest edges than in prior studies. These results are preliminary as we look to add additional 2020 or 2021 datasets. This study suggests that migratory tree bats exhibit broad geographic variation in foraging and roosting ecology, which may warrant further consideration and study as U.S. wind facilities are frequently constructed in open areas away from forest.

94: High-Fidelity Modeling of Eagle Soaring Habitats Near Wind Plants in Complex Terrain

Presenter: Regis Thedin (National Renewable Energy Laboratory, U.S.)
Authors: Regis Thedin (National Renewable Energy Laboratory, U.S.), Eliot Quon (National Renewable Energy Laboratory, U.S.), Michael Lawson (National Renewable Energy Laboratory, U.S.), Charles Tripp (National Renewable Energy Laboratory, U.S.), Rimple Sandhu (National Renewable Energy Laboratory, U.S.), Caroline Draxl (National Renewable Energy Laboratory, U.S.), Bethany Straw (National Renewable Energy Laboratory, U.S.), Todd Katzner (U.S. Geological Survey, U.S.), Chris Farmer (Western EcoSystems Technology Inc., U.S.)
Abstract: As wind energy development increases, so does the potential for wind farms to impact eagle populations. Although tools and strategies for how to best site wind farms to avoid such conflicts have been developed over the last two decades, nonetheless, we have limited ability to quantify, prior to operation, the risk that a wind farm poses to eagle populations. This leaves both wildlife and the wind energy industry at risk. Eagles, as obligate soaring birds, rely on atmospheric updrafts to offset the large energy requirements for flapping flight. Accordingly, understanding how eagles interact with atmospheric flow is a key component to predicting eagle movements and understanding how to design wind farms to minimize risk to eagles. While wildlife researchers have recently begun to incorporate

wind resource information into eagle risk assessment tools and studies, to date, only coarse atmospheric flow information has been used.

To improve understanding of how eagles interact with atmospheric flows, we use a state-of-the art model to investigate atmospheric flow at a site in the U.S. Mountain West that is home to four adjacent wind farms that present different risk to eagles. Specifically, we characterize and quantify the differences encountered in flow fields under canonical conditions that are representative of atmospheric conditions for each wind farm. Our model resolves terrain, buoyancy induced by convective heating from the ground, and turbulence down to 30-m grid resolution, can then be used to predict the velocity and temperature field.

For the development of the wind-plant-scale simulations, we first estimate typical wind speed and direction by season and time of the day, using regional-scale weather simulations. Next, the sites are represented by 30-m resolution terrain data available from the NASA Shuttle Radar Topography Mission. Time-accurate large-eddy simulations of the atmospheric boundary layer are executed under the representative scenarios previously identified to characterize the soaring habitat. Canonical unstable and neutral atmospheric stability scenarios are investigated, comparing the flow fields at the different sites. Differences between average orographic and thermal updrafts are assessed, as well as turbulent kinetic energy and other metrics that may indicate possible divergences. We have been able to capture high resolution vertical velocity fields for a variety of operating conditions. These preliminary results highlight terrain induced variability for mean and fluctuating velocity fields allowing us to resolve individual thermal plumes. The results of this modeling effort show the frequency, location and strength of various flow features.

The investigation and comparison of the flow fields at the different sites during different seasons will offer insight into the different flow features that may be favored by the eagles and how they interact with the complex environment. By comparing these results to data collected from telemetered eagles moving through the area, we will identify co-variates that influence eagle movement that may not otherwise be observable. The outcomes of this work will ultimately be incorporated into a microscale eagle behavior model that can predict eagle behavior around wind farms.

97: Assessment of Marbled Murrelet (Brachyramphus marmoratus) Movements and Potential Collision Risk in Northern California.

Presenter: Robert Roy (Stantec Consulting Services Inc., U.S.)
Authors: Robert Roy (Stantec Consulting Services Inc., U.S.), Richard Golightly (H.T. Harvey & Associates, U.S.), Stephanie Schneider (H.T. Harvey & Associates, U.S.), Yasmine Akky (Stantec Consulting Services Inc., U.S.), Kevin Martin (Terra-Gen, U.S.)
Abstract: Two years of radar surveys were conducted to facilitate detailed collision risk models (CRMs) for a wind project proposed within the inland nesting range of the federally threatened marbled murrelet (*Brachyramphus marmoratus*) in Humboldt County, in northern California. Radar surveys utilized two dual-radar systems operating simultaneously at each of eight survey locations. The CRMs included a deterministic model and probabilistic model, which provided a single estimate of annual collision risk and a quantification of the variation in risk along with an upper limit of potential risk each year, respectively. Radar sampling was temporally and spatially intense. The radar sampling was novel in that it included 1) a greater frequency of surveys so as to capture the temporal dynamics in passage rate (year round), 2) radar coverage included most of the proposed turbine string including murrelet approaches to the ridge with the turbines, 3) surveys were conducted at peak activity times as well as at

alternative flight times to ensure a complete quantitative picture of the daily traffic patterns to inform the CRMs, and 4) surveys went beyond the normal protocols for radars with murrelets so as to discriminate actual times of flight and associate timing with the availability of ambient light including moonlight. Therefore, the radar data provided detailed insight on murrelet movements relative to the site-specific topography, corroborated patterns in murrelet activity and distribution in the area that was known from previous radar and visual-acoustic surveys in the region, and provided murrelet activity metrics for the CRMs. The CRMs indicated that, for a species like marbled murrelets with such specific and predictable daily movement patterns, modeled risk based on radar data had the power to inform siting decisions and significantly reduced an initial potential take of murrelets.

98: Leveraging machine learning to identify marine birds and mammals in digital photographic aerial surveys of the Pacific Outer Continental Shelf off central and southern California, USA

Presenter: Cheryl Horton (U.S. Geological Survey, Western Ecological Research Center, U.S.)
Authors: Cheryl Horton (U.S. Geological Survey, Western Ecological Research Center, U.S.), Laney White (U.S. Geological Survey, Western Ecological Research Center, U.S.), Josh Adams (U.S. Geological Survey, Western Ecological Research Center, U.S.), Abram Fleishman (Conservation Metrics Inc., U.S.), Matthew McKown (Conservation Metrics Inc., U.S.), David Pereksta (Bureau of Ocean Energy Management, U.S.)
Abstract: From 2018 to 2021, the U.S. Geological Survey's Western Ecological Research Center, with support from the Bureau of Ocean Energy Management, is conducting aerial digital photographic surveys of the Pacific Outer Continental Shelf (POCS) off California, including the Morro Bay and Diablo Canyon offshore wind call areas. Surveys are conducted during different oceanographic seasons and include fall and spring migratory periods. During each season, survey transects provide broad spatial coverage and generate an archivable record of ~100,000 high-resolution digital images with associated sensor data. New analytic machine learning methods are required to process this volume of data. Because machine learning and computer vision techniques are rapidly evolving, appropriate, comprehensive image libraries for target detection and classification do not yet exist for at-sea aerial survey imagery. Classified image libraries (training data) are used to effectively "teach" algorithms what to look for. Through collaboration with Conservation Metrics Inc., we developed a labeled training dataset and an independent test dataset. Presently, we are evaluating object detection and classification algorithms. After completing surveys in January 2021, we will use our best model to extract and classify marine bird and mammal objects in the full, multiyear image dataset. Based on our imagery and species present off California, we are developing standardized identification guides for marine birds and mammals and will use human reviewers to re-assign labels to species or taxonomic groups. Annotated images, training, and test datasets will be made publicly available in order to kick-start similar survey efforts in the future. Once individual marine birds and mammals are identified and enumerated, we will estimate regional abundances, density patterns, and map observed seasonal species distributions. We plan to compare 2018–21 results with human-observer-based surveys from low-flying aircraft conducted historically (1980's and 1999–2002) in this region. Here, we describe techniques that have potential for long-term monitoring that can quantify pre-construction baseline conditions and assess the effects on marine wildlife within the POCS during the construction and operation of offshore wind projects.

99: A Cross-Taxa Test of Hypotheses for Why Bats are Killed by Wind Turbines

Presenter: Erin Baerwald (University of N, Canada)
Authors: Erin Baerwald (University of N, Canada), R. Mark Brigham (University of Regina, Canada)
Abstract: Wind turbines are a rapidly increasing means of generating electricity, and although wind energy is relatively environmentally friendly, it is not without ecological impacts. One concern is the

large number of bats killed at some wind energy facilities. While there are many hypotheses that have been proposed to explain these fatalities, currently there are no definitive answers. We took a novel approach to evaluate the various hypotheses by using data on fatality rates of Nightjars (Order: *Caprimulgiformes*), a threatened avian order that are ecologically similar to the bats killed most frequently at turbines across North America, the Lasiurine bats. We predicted that if the reason for collisions is general to nocturnal aerial-hawking insectivores, fatality rates at wind turbines should be similar across taxa. If fatality rates differ across taxa, then the reasons for fatalities are more specific to the Lasiurine bats. We used the Bird Studies Canada Wind Energy Bird and Bat Monitoring Database for data on fatality rates within Canada and the American Wind Wildlife Information Centre Database for data on fatality rates within the United States. These data indicate that fatalities of Nightjars at wind turbines are three orders of magnitude lower than for bats, even at the same sites. This lends support to the idea that the reason for high numbers of bat fatalities is related to being a bat (e.g. roost attraction, mating behaviour, and/or anatomy) and not to being a nocturnal aerial-hawking insectivore (i.e. foraging).

101: Unmanned aerial systems equipped with thermal cameras as a potential method for detection of hibernacula used by bats.

Presenter: Michael Gerringer (Western EcoSystems Technology, Inc. (WEST), U.S.)
Authors: Michael Gerringer (Western EcoSystems Technology, Inc. (WEST), U.S.), Timothy Sichmeller (Western EcoSystems Technology, Inc. (WEST), U.S.), Kimberly Bay (Western EcoSystems Technology, Inc. (WEST), U.S.)
Abstract: WEST tested an unmanned aerial system (UAS; or 'drone') equipped with a thermal camera as a potential method for locating and describing new potential hibernacula used by bat species during the winter season. By using thermal imagery, subtle differences in environmental temperatures across a wide area of interest can be detected during UAS flights along bluffs, rocky outcrops, and talus areas in winter. During February 2020, WEST flew a multi-rotor UAS along bluffs at different locations in Iowa, using the live feed from the thermal camera to detect and record potential bat hibernacula by looking for areas warmer than the ambient temperature along the bluffs. If temperature differences were detected, it was photographed and the GPS coordinates and temperature of the potential opening was recorded. During April 2020, WEST deployed acoustic detectors near each potential hibernacula identified during February 2020 UAS surveys in order to confirm the presence or absence of bat species utilizing the locations found as potential winter hibernacula. Upon collection of the acoustic detectors, recorded bat calls will be analyzed to determine species. This unique method could allow for the detection of potential bat hibernacula in suitable areas near proposed wind energy projects that are inaccessible by other means (i.e. human or dog searches by foot). Of particular interest would be the identification of hibernacula of federally listed bat species.

102: Development of a meteorological data set to support research of volant species

Presenter: Caroline Draxl (National Renewable Energy Laboratory, U.S.)
Authors: Caroline Draxl (National Renewable Energy Laboratory, U.S.), Michael Lawson (National Renewable Energy Laboratory, U.S.), Chris Farmer (Western EcoSystems Technology Inc., U.S.), Todd Katzner (U.S. Geological Survey, U.S.), Eliot Quon (National Renewable Energy Laboratory, U.S.), Rimple Sandhu (National Renewable Energy Laboratory, U.S.), Bethany Straw (National Renewable Energy Laboratory, U.S.), Regis Thedin (National Renewable Energy Laboratory, U.S.), Charles Tripp (National Renewable Energy Laboratory, U.S.)
Abstract: Uncovering drivers of risk is crucial to understanding interactions between wildlife and wind turbines, and identifying options for impact minimization. These drivers tie to co-variates linked to

behavior and movement patterns that allow us to estimate locations and periods of risk. For volant species, atmospheric flow can have significant influence on flight patterns. For obligate soaring birds, like golden eagles, updraft velocities can inform where eagles are likely to travel, at what altitude, and where conditions are not likely sufficient to sustain soaring flight. This has been an active area of study in recent years, using relatively coarse atmospheric data generally at the 20km x 20km scale or larger. Leveraging a 20-year dataset from the Weather Research and Forecasting Model (WRF) (https://www.mmm.ucar.edu/weather-research-and-forecasting-model), we are quantifying vertical velocities across the continental United States at a 2km x 2km resolution.

Wind resource data sets originally were static maps showing the mean annual wind speed over an area. However, for these data sets to be optimally used for various applications they must be high-resolution time series, seamlessly span large geographic contexts, and account for uncertainty in wind speed. The National Renewable Energy Laboratory is producing public available datasets that meet these criteria and will be bias corrected to yield the most accurate wind resource data. This effort is an augment to the current WIND Toolkit which houses a high resolution data set. In the new iteration of the WIND Toolkit, a 20-year dataset will be used to improve the accuracy and estimate uncertainty using ensemble and machine-learning techniques. The resulting product will be the most accurate dataset of its size and at a 2km x 2km spatial and 5-minute temporal resolution.

Through this work, a mesoscale vertical velocity layer will be produced by calculating the likelihood of orographic updraft and thermal updraft conditions across the continental United States. Specifically, we will use WRF model output combined with digital elevation maps to predict updrafts and then determine if vertical velocities are sufficient to support golden eagle soaring and gliding. Ultimately this data layer will be made available as a GIS layer in the Wind Prospector (maps.nrel.gov/wind-prospector/) tool or a similar framework. Data that will be incorporated include wind speed, direction temperature, relative humidity, barometric pressure, air density, precipitation rate, solar radiation, atmospheric stability, skin temperature, and upward heat flux. These products will advance research on interactions between volant species and wind energy by providing open access to highly resolved data with uncertainty quantification not previously available at this scale.

104: National-Scale Impacts on Wind Energy Production under Curtailment Scenarios to Mitigate Bat Fatalities

Presenter: Galen Maclaurin (National Renewable Energy Laboratory, U.S.)
Authors: Galen Maclaurin (National Renewable Energy Laboratory, U.S.), Cris D. Hein (National Renewable Energy Laboratory, U.S.), Bethany Straw (National, U.S.), Eric Lantz (National Renewable Energy Laboratory, U.S.), Nick Gilroy (National Renewable Energy Laboratory, U.S.), Grant Buster (National Renewable Energy Laboratory, U.S.), Anthony Lopez (National Renewable Energy Laboratory, U.S.)
Abstract: Estimates of bat fatalities at wind energy facilities are in the hundreds of thousands per year across North America. Curtailment to reduce bat-turbine collisions is an evolving practice predominantly founded on an association between wind speed and bat activity during high-risk months of the year. Research at existing wind plants has found curtailment strategies to reduce fatalities by up to 50%, while reduction in annual energy production (AEP) can range from 1 to 3%. As we move towards a future where bats can coexist with wind turbines, we must consider solutions that address bat mortality and population sizes as well as power production and financial viability of wind energy. In this study we applied different curtailment regimes across the entire contiguous U.S. (CONUS) at 2km resolution and examined sensitivities of potential AEP reduction and how that related to costs and financial viability for

new wind projects. We applied nighttime curtailment scenarios based on previous studies that varied wind speed cut-in and curtailment months alone (blanket curtailment) and in combination with temperature and precipitation rate thresholds (smart curtailment). We examined moderate curtailment (<5 m/s July through October) and high curtailment (<6.9 m/s April through October). In the final results of the study, we found that AEP reduction can range across the country from less than 1% to 8% for different curtailment regimes. We observed that wind speed cut-in and months of curtailment impact AEP reduction more than temperature and precipitation rate. However, locations with lower nighttime temperatures and more periods of rain showed substantial benefit from smart over blanket curtailment. For example, in the mid-Atlantic region smart vs blanket curtailment mitigated AEP reduction by up to 26%. From an estimated 11.6TW of potential wind capacity across CONUS, we found that—in terms of positive vs negative net present value—the high curtailment scenario could remove 976 GW of that capacity, while applying the moderate curtailment scenario instead would gain back about 90% of that lost capacity (a 101 GW loss). Up to this point we assumed that when scenario conditions were met, bats would be active and curtailment would be required. Delving deeper, we explored the potential value of bat detection technology within a regional context and estimated how much AEP loss could be mitigated. Assuming that bats are active at a location 25% of the time during the night, we demonstrated that effective bat detection could potentially make wind energy financially viable in regions that might otherwise be overlooked. While this analysis did not include the cost of detection instrumentation, our results showed that some regions could potentially benefit from or might require detection technology with curtailment to be financially viable. While AEP reduction from moderate curtailment was less than 1%, during months of curtailment power production can be reduced by up to 5%. This research brings the question of bat curtailment into national-scale modeling and long-term energy planning through improved representation of operational constraints for wind energy deployment.

106: Genetics 101: Applications for the Wind Industry

Presenter: Elizabeth Baumgartner (Western Ecosystems Technology, Inc., United Kingdom)
Authors: Elizabeth Baumgartner (Western Ecosystems Technology, Inc., United Kingdom), Victoria Zero (Western EcoSystems Technology, Inc. (WEST), U.S.), Michael Tabek (Western EcoSystems Technology, ULC, Canada)
Abstract: Migratory tree bats, such as hoary bats, compose the majority of bat fatalities found at wind energy facilities. Determining population size and demographics provides a framework within which we can assess the impact of wind-related fatalities on bat populations; however, limited demographic data exist for migratory bat species. For taxa that are notoriously difficult to study, such as migratory tree bats, genetic analysis provides a method to estimate bat population demographics, including genetic diversity, population structure, effective and census population size, temporal trends in population size, and population viability. The most readily available bat genetic material to the wind industry can be harvested from carcasses found at wind facilities; however, we can also harvest genetic material from live captures, museum specimens, and eDNA (e.g., guano) left in roosts and hibernacula. Our objective is to provide a primer on sample collection and storage methods, analytical methods and techniques, and potential applications of genetic analyses in assessing the direct effects of wind development on bat populations. We will also present a brief summary of research published to date, identifying knowledge gaps and research opportunities to further understand bat populations. Lastly, we summarize challenges concerning genetic analysis of bats specific to wind development research questions. Many institutions are working on genetic research, and carcasses found and collected across the country provide opportunities for the wind industry to support efforts to understand the nature of bat populations and increase the value of post-construction fatality monitoring.

108: Reducing Bat Fatalities Using Ultrasonic Acoustic Deterrent Technology: A Potential Mechanism for Conservation at Offshore Wind Energy Sites

Presenter: Danielle O'Neil (Harvard Extension School, U.S.)
Authors: Danielle O'Neil (Harvard Extension School, U.S.), Cris D. Hein (National Renewable Energy Laboratory, U.S.), Sara P. Weaver (Bowman Consulting Group, U.S.)
Abstract: In 2015, the U.S. Department of Energy estimated that by 2030 wind power generation would reach 224 GW. While land-based wind projects (LBW) still dominate deployment in the U.S., several offshore-based wind projects (OBW) are anticipated in the next decade. With this increase in wind energy development, which is critical for reducing greenhouse gas emissions and mitigating the effects of climate change, the potential for increased wildlife conflict is a concern, particularly with bats. Twenty-seven of the 47 U.S. bat species have been found as representative fatalities at LBW. Insectivorous bats are echolocating mammals that use ultrasonic frequencies to hunt and avoid obstacles in air space. Technology such as ultrasonic acoustic deterrent (UAD) devices that emit high frequency sound, have been used on LBW projects with mixed but generally positive results. UADs placed on wind turbines presumably cause echolocation disorientation within the ensonified airspace potentially diverting bats from approaching wind turbines and thus, reducing bat-related collision fatalities. A primary objective of this project was to use data from LBW projects that employed UADs to assess their applicability at OBW. A secondary objective was to determine abiotic factors that had effects on bat activity around wind turbines. My assumptions were that UADs were effective at deterring bats from the ensonified areas of wind turbines and that high wind velocities, low barometric pressure, and decreasing temperatures during seasonal migrations altered bat activity around wind turbines.

I analyzed data from existing bat studies using UADs at three North American LBW. Using generalized linear mixed modeling (GLMM), I identified abiotic variables that influence how and when bats interact with LBW. I compared these factors to wind energy sites that deployed UADs on some turbines, with other turbines used as controls. For the first model, the GLMM results showed that presence of operational UADs on LBW treatment wind turbines was statistically significant ($p < 0.001$) at reducing bat fatality events when compared to control wind turbines. For the second model, there was no statistically significant effects from any of the three abiotic variables on bat fatality reductions at treated LBW turbines. However, in model 3, average nightly wind speed was statistically significant at control LBW turbines. The results indicate that UADs are effective at reducing bat fatality events at LBW. Results also showed that wind speed significantly affected bat fatality at wind turbines without deterrent technology. To inform siting and operating strategies at OBW, lessons from LBW, such as deploying UADs and monitoring bat activity based on nightly wind fluctuations may provide insight on how to practicably reduce bat fatality events.

109: Estimating the Likelihood that Wind Turbines cause Barotrauma in Bats

Presenter: Michael Lawson (National Renewable Energy Laboratory, U.S.)
Authors: Michael Lawson (National Renewable Energy Laboratory, U.S.), Dale Jenne (National Renewable Energy Laboratory, U.S.), Robert Thresher (National Renewable Energy Laboratory, U.S.), Bethany Straw (National, U.S.)
Abstract: Bat mortality caused by operating wind turbines is an issue of concern for wind energy and wildlife stakeholders. One theory to explain the high bat mortality rates around wind farms is that bats are killed by barotrauma that results from exposure to the pressure variations caused by rotating turbine blades. No research has compared pressure changes that bats may be exposed to when flying

near wind turbines to pressures that are likely to cause barotrauma in bats. To advance the scientific knowledge in this area, we performed computational fluid dynamics simulations and analytical calculations to estimate the pressures bats could experience when flying near a turbine blade or blade-tip vortex caused by a utility-scale wind turbine. We compared our results to pressure changes that cause barotrauma and mortality in other mammals of similar size, as there are no published estimates for pressure levels that cause barotrauma in bats. The results show the magnitude of the low-pressures that bats are exposed to near wind turbines is approximately eight times smaller than the pressure that causes mortality in rats. High-pressures that bats may experience are approximately 80 times smaller than the pressure level needed to cause 50% mortality in mice, which have a body mass similar to several bat species that are impacted by wind energy facilities. Perhaps most significantly, our results indicate that bats must take specific and unlikely flight paths to be exposed to the largest magnitude of low- and high-pressures caused by turbines. If bats deviate even slightly from these flight paths, they are struck by the blades or experience smaller pressure change. These results suggest that if bats have a physiological response to rapid low- and high-pressure exposure that is similar to other mammals it is unlikely that barotrauma is responsible for a significant number of bat deaths caused by wind turbines, and that impact trauma is the more likely cause of turbine-related bat fatalities. It is important to note that the solution to the problem of bat fatalities caused by wind turbines is independent of the proximate cause of the fatalities-develop deterrents and curtailment strategies to limit the potential for turbines to cause fatalities.

111: Quantifying Turbine-Level Risk to Golden Eagles Using a High-Fidelity Updraft Model and a Stochastic Behavioral Model

Presenter: Rimple Sandhu (National Renewable Energy Laboratory, U.S.)
Authors: Bethany Straw (National Renewable Energy Laboratory, U.S.), Rimple Sandhu (National Renewable Energy Laboratory, U.S.), Charles Tripp (National Renewable Energy Laboratory, U.S.), Michael Lawson (National Renewable Energy Laboratory, U.S.), Eliot Quon (National Renewable Energy Laboratory, U.S.), Regis Thedin (National Renewable Energy Laboratory, U.S.), Caroline Draxl (National Renewable Energy Laboratory, U.S.), Chris Farmer (Western EcoSystems Technology Inc., U.S.), Todd Katzner (U.S. Geological Survey, U.S.)
Abstract: To minimize the effects of wind farms on golden eagle (*Aquila chrysaetos*) populations while enabling sustainable development of renewable energy resources, it is important to understand how eagles interact with atmospheric flows, terrain features, and anthropogenic structures. Models that predict migratory flight paths provide one tool that helps us grasp how the location of wind farms may influence interactions and impacts on migrating golden eagles. The current state-of-the-art in predicting migratory flight paths uses a deterministic fluid-flow analogy to predict eagle trajectory using only an orographic updraft potential computed from topographical features. This model does not take into account variables, such as thermal updrafts and time varying atmospheric conditions that are known to influence migratory behavior. In this work, we improve on the model with the objective of developing tools that advance our understanding of how atmospheric flows and terrain features affect migratory eagle behavior and their interactions with wind farms. Specifically, we: 1) incorporate both orographic and thermal updraft information in simulating eagle flight paths; 2) incorporate stochasticity into eagle travel patterns to better capture the influence of exogenous factors on, and the inherent stochasticity of eagle behavior; 3) consider spatio-temporal atmospheric data at wind-farm-scale when computing updraft potential; and 4) account for how atmospheric conditions and the direction of migration change seasonally and how these changes affect eagle migratory flight behavior. We tested the model using a 50km by 50km region with 50 m resolution in the western United States. We simulated 900 independent, probabilistic eagle tracks during southerly and northerly migration, assuming eagles solely

rely on orographic updrafts. The preliminary results indicate that the inclusion of finer resolution atmospheric data allows for the inclusion of realistic conditions that an eagle experiences. The stochasticity in eagle tracks provides a platform to include uncertainty in eagle decision making and help produce robust eagle presence maps. We will deploy updraft and downdraft velocities computed using a high-fidelity, wind farm scale, computational fluid dynamics solver under development at National Renewable Energy Laboratory. This work is a first step in the development of a predictive and generalizable eagle behavior model at the wind farm scale that does not rely on empirical data collection. Although the current model is intended for migratory eagles, we will extend and refine this model to inform the development of additional behavioral modes, including resident eagle behavior. This modeling approach improves our ability to understand eagle use of the landscape at a fine scale, and it is our hope that this work will ultimately help advance strategies that minimize the impact of wind development on golden eagle populations.

112: Habitat use acoustics for preconstruction turbine micro siting

Presenter: Adam Rusk (Stantec Consulting Services Inc., U.S.)
Authors: Adam Rusk (Stantec Consulting Services Inc., U.S.)
Abstract: Stantec is taking novel approaches to provide information about bat activity for our clients with respect to micro-siting turbines. A commonly accepted setback from bat habitat is 1,000 feet, which was originally developed for Indiana bats (*Myotis sodalis*). However, not all target bat species respond to their habitat the same way, and other species, such as the northern long-eared bat (*Myotis septentrionalis*) or the gray bat (*Myotis grisescens*) may require different micro-siting of turbines to minimize impacts. A lack of site-specific and species-specific turbine setback constraints can lead to unnecessary restrictions in micro-siting. To account for these nuances in species and local population habitat use, Stantec performed stratified acoustic sampling at two pre-construction wind facilities in southwest Missouri. The purpose of these two surveys was to evaluate if a 1,000-ft setback from streams is necessary or sufficient for minimizing turbine interaction with gray bats. Fifty acoustic bat detectors were set out at each project for five to seven nights (site-specific) and nights where all detectors were running concurrently were used to quantify gray bat activity. Stantec manually vetted all calls to identify those that were characteristic of gray bats. Using gray bat passes per detector night as a response variable we used Tweedie regressions to predict gray bat activity throughout the entire project. This created an "activity surface" which predicted what gray bat activity at any point in the project given habitat variables. The best model was used to identify which variables were most important in predicting gray bat activity. When evaluating both projects together Stantec found that distance to maternity cave roosts is a major factor in predicting activity levels but also depends on the primary direction the bats travel from the colony. Area of forested cover and distance to trees and streams were also important variables in one of the models. Importantly, Stantec observed that recorded activity levels of gray bats diminished drastically immediately outside the stream corridor. The highest activity sites were immediately adjacent to streams and increasing distance consistently resulted in substantial decreases in recorded activity. Initial pre-construction results suggest limiting construction near quality habitat in close proximity to cave roosts. However, 1,000 feet may be overly conservative and site-specific data could allow for turbine siting closer to heavily-used riparian corridors without increasing risk to gray bats. Additional surveys performed post-construction, accounting for potential attraction to turbines, could substantiate the results of these surveys.

116: Simple curtailment in Australia, a compromise between bat mortality and energy production.

Presenter: Emma Bennett (PhD Student, Australia)
Authors: Emma Bennett (PhD Student, Australia)

Abstract: We investigated the effectiveness of turbine curtailment on reducing the incidence of southern bent wing bat (*Miniopterus orianae bassanii*) collisions at Cape Nelson North Wind Farm, Victoria, Australia. This was the first wind farm which has investigated the effectiveness of curtailment on bats in Australia. The study was a before/after experimental design with repeated methodology in 2018 (pre-curtailment) and again in 2019 (post curtailment) which comprised carcass searches twice weekly at all 11 turbines using trained detection dogs; bat activity monitoring (audio) throughout the period; and daily weather data records. Due to low numbers of the target bats, all bat collisions were recorded and changes in overall bat mortality was investigated. Curtailment was simplified to all turbines from dusk till dawn with the cut in wind speed raised from 3m/s to 4.5m/s for the late summer and early autumn months of January to April. There was no significant difference in bat activity between the years of the study and a 54% reduction in all bat mortality which can be attributed to the curtailment.

While simple curtailment may be a crude option when compared to smart curtailment options offered in Europe and North America, information on bat behavior and flight activity is not available for local species and action to reduce impacts needed to be taken. Without legislative guidance, the operators of the facility opted to investigate curtailment and voluntarily adopted the change in operations once the study was complete. Loss of power production was minimized by the small alteration to cut-in speed while mortality rates were halved, which satisfied the operators and provided leadership in reducing bat mortality where legislative guidance was lacking. The cost of the original mortality monitoring for the initial two-year period prior to this study exceeded the loss of revenue from curtailment accrued to this day and beyond.

This study demonstrates that curtailment is an effective measure to reduce bat fatalities at wind farms for Australian bat species. In addition, we consider the financial cost of curtailment in comparison to the increasing cost and intensity of mortality monitoring in Australia. We have demonstrated that small changes to cut-in wind speed can have a significant impact in reducing bat mortality and may be a viable alternative to costly mortality studies in regions where funding for mortality studies is limited, information on local bats is scarce, or bat populations are particularly vulnerable.

118: Autumnal Movement by "Tree" Bats on the Mid-Atlantic Coast: Evidence from the Motus Wildlife Tracking System and Stationary Acoustics

Presenter: Michael True (Virginia Polytechnic Institute and State University, U.S.)
Authors: Michael True (Virginia Polytechnic Institute and State University, U.S.), W. Mark Ford (Virginia Polytechnic Institute and State University, U.S.)
Abstract: Tree bats (*Lasiurus spp., Lasionycteris noctivigans*) comprise most wind turbine collision fatalities among North American bats, particularly during the August through November period of southward movement, mating, and juvenile dispersal. While evidence points to a concentration of migrating bats near or off-shore as bats travel from New England and Canada in autumn, data gaps exist for most coastal regions where large-scale off-shore wind turbine development is planned or being constructed. For portions of the mid-Atlantic coast such as the Delmarva Peninsula and southern New Jersey where the mainland is bracketed by the Atlantic Ocean and large embayments (i.e., Chesapeake Bay and Delaware Bay), the extent of both onshore and offshore/over-water flights by migratory bats is unknown. In conjunction with the Motus Wildlife Tracking System program, we captured and radio-tagged 44 eastern red bats (*Lasiurus borealis*) in southern New Jersey, coastal Delaware and the Eastern Shore of Virginia. Results from 2019 suggest semi-consistent autumnal movement directly across both the Chesapeake and Delaware bays during the autumnal period, an area where interest in wind turbine

development is increasing and tree bat collision risk is high. Stationary detectors deployed continuously since 2012 on barrier islands off the Eastern Shore generally showed low levels of bat activity except on islands where forests and fresh water was present. However, peaks of activity did occur in the autumn at most sites suggestive of some migratory pulse this far south. Nightly acoustic activity was strongly related to precipitation, wind and temperature. Collectively, these efforts may provide insights for mitigation strategies to help minimize potential impacts from wind-energy to bats in the mid-Atlantic.