# State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts

Virtual Event Hosted by the
**New York State Energy Research and Development Authority (NYSERDA)**

## November 16-20, 2020

https://www.nyetwg.com/2020-workshop

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# Welcome to the Virtual State of the Science Workshop!

If any technological issues crop up during the workshop, please contact Edward.jenkins@briloon.org

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# About the State of the Science Workshop

Under the aegis of the Environmental Technical Working Group (E-TWG), the New York State Energy Research and Development Authority (NYSERDA) has convened the second State of the Science Workshop on Wildlife and Offshore Wind Energy. State of the Science Workshops engage stakeholders in expert information exchange and discussion, and promote regional coordination and collaboration on offshore wind and wildlife issues. While the first workshop in 2018 was broadly focused on understanding wildlife interactions with offshore wind energy development, the 2020 workshop will focus specifically on improving our understanding of cumulative impacts to wildlife. Learn more about the E-TWG and the 2018 workshop at nyetwg.com.

## 2020 Workshop Goals

1. Assess the state of the knowledge regarding offshore wind development's cumulative effects on populations and ecosystems, and
2. Develop a research agenda of key studies that could be conducted in the next 3-5 years to improve our understanding of cumulative biological impacts as the offshore wind industry develops in the eastern United States

# Acknowledgements

The State of the Science Workshop on Wildlife and Offshore Wind Energy Development is funded by the New York State Energy Research and Development Authority (NYSERDA) and planned by the Biodiversity Research Institute (BRI) and Cadmus Group with support from NYSERDA, a workshop planning committee, and members of the Environmental Technical Working Group (E-TWG). We wish to thank the following individuals for their support in planning the workshop:

**Workshop Planning Committee:** Iain Stenhouse, *Biodiversity Research Institute* • Kyle Baker and David Bigger, *Bureau of Ocean Energy Management* • Bonnie Brady, *Long Island Commercial Fishing Association* • Lauren Kubiak, *Natural Resources Defense Council* • Sherryll Huber Jones, *New York Dept. of Environmental Conservation* • Sophie Harfield Lewis, Madeline Hodge, Laura Morse, *Ørsted* • Carl Lobue, *The Nature Conservancy* • Scott Johnston and Pamela Loring, *U.S. Fish & Wildlife Service* • Douglas Zemeckis, *Rutgers University* • Ruth Perry, *Shell New Energies* • Cristiana Bank and Elizabeth Hansel, *Vineyard Wind* • Howard Rosenbaum, *Wildlife Conservation Society*

**Environmental Technical Working Group Members and Alternates:** Kate McClellan Press and Gregory Lampman, NYSERDA *(Convener/Chair)* • Jennifer Daniels and Paul Phifer, *Atlantic Shores* • Jillian Liner, *Audubon New York* • Jenny Briot, *Avangrid Renewables* • Isis Johnson Farmer and Brandi Sangunett, *Bureau of Ocean Energy Management* • Shannon Kearney, *Connecticut Dept. of Energy and Environmental Protection* • Kimberly Cole and Laura Mensch, *Delaware Dept. of Natural Resources and Environmental Control* • Julia Bovey, Martin Goff, and Laura Morales, *Equinor* • Catherine McCall, *Maryland Dept. of Natural Resources* • Lisa Engler, *Massachusetts Dept. of State* • Keith Hanson and Sue Tuxbury, *National Oceanic and Atmospheric Administration* • Catherine Bowes, *National Wildlife Federation* • Ali Chase, Nathanael Greene, and Francine Kershaw, *Natural Resources Defense Council* • Anthony Bevacqua, *New Jersey Board of Public Utilities* • Megan Brunatti and Kevin Hassell, *New Jersey Dept. of Environmental Protection* • Sherryll Huber Jones, *New York Dept. of Environmental Conservation* • Terra Haight, *New York Dept. of State* • Joe Martens, *New York Offshore Wind Alliance* • Liz Gowell, Mike Evans, and Stephanie Wilson, *Ørsted* • Koen Broker, Louis Brzuzy, and Ruth Perry, *Shell New Energies* • Carl Lobue, *The Nature Conservancy* • Scott Johnston and Pam Loring, *U.S. Fish & Wildlife Service* • Matt Robertson, *Vineyard Wind* • Laura McKay, *Virginia Dept. of Environmental Quality* • Howard Rosenbaum, *Wildlife Conservation Society*

**NYSERDA Support Staff:** Adrienne Downey • Alicia Knapp • Janna Herndon • Lisa Romero • Morgan Brunbauer

**Workshop Organizers:** Kate Williams, Edward Jenkins, and Julia Gulka, *Biodiversity Research Institute* • Ashley Arayas, Jacqueline Sharry, and Katie Browning, *Cadmus Group* • Kate McClellan Press and Lisa Romero, *NYSERDA*

**Technical Program Chair:** Kate Williams, *Biodiversity Research Institute*

**Many thanks to the workshop speakers, lightning talk presenters, work group technical leads, and all attendees for your involvement in this workshop!**

# Workshop Platform

Workshop events are being held virtually through the Whova event platform and can be accessed via web browser or using Whova's mobile application. Please visit nyetwg.com/workshop-logistics for more information.

# Workshop Policies

## Code of Conduct

All participants are expected to behave in a professional and appropriate manner in all conference venues and conference social events. Please see our Doing Business with NYSERDA webpage for NYSERDA's policies, including its harassment and discrimination policy. This policy applies to all conference participants.

Inappropriate behavior during conference activities includes the following:

- Harassment, intimidation, or discrimination in any form.
- Verbal abuse of any attendee, speaker, or support staff member.
- Disruption of presentations.
- Inclusion of promotional materials in presentations, postings, and messages.
- Copying presentations, Q&A, verbal or written discussions, or chat room activity that takes place in the virtual space. This includes taking screen shots, making audio or visual recordings, and distributing said copies or recordings (via social media or any other means). Please be respectful of speakers and do not take or distribute pictures of or copy presentation materials without explicit permission from the speaker.

**Concerns and questions about this policy should be directed to workshop organizers at edward.jenkins@briloon.org.**

## Communication Guidelines

The convening parties of the workshop maintain responsibility for all press communications about the project. This event is a workshop and is not intended for the media. We respectfully request that participants contact the workshop planning team regarding distribution of information related to the project.

## Data Privacy

The 2020 virtual Workshop will occur within the event platform Whova. The Whova privacy policy is available here. If you choose to participate in the State of the Science Workshop you are also consenting to the following: Representatives of the State of the Science Workshop will be recording video sessions for attendees to view on the Whova website for up to six months after the last day of the event (May 20, 2021). Q&A, Community Boards, Session Chats, and Polls will be saved for the same amount of time. Written workshop proceedings will be made public following this event, but comments and information provided in the Q&A, Community Boards, Session Chats, and Polls will not be attributed to an individual or organization (except in the case of workshop speakers answering questions about their own presentations). The State of the Science Workshop and NYSERDA may use the email you provided to contact you about future State of the Science events and proceedings, which you can opt out of at any time.

# Agenda

All times are listed in Eastern Standard Time. Click the title of lightning talks in the agenda to jump to the respective abstract.

## Monday, November 16

| ***Session 1: Framework for Understanding Cumulative Impacts from Offshore Wind.*** *Moderator: Howard Rosenbaum, Wildlife Conservation Society*<br>10:30 am – 12:30 pm EST | |
|---|---|
| 10:30 am | *Virtual Check-in* |
| 10:45 am | **Opening Remarks from NYSERDA**<br>Doreen Harris, *Acting President and CEO of NYSERDA* |
| 10:50 am | **Welcome and setting the stage**<br>Greg Lampman, *NYSERDA* |
| 11:05 am | **Cumulative anthropogenic impacts on the world's oceans**<br>Sara Maxwell, *University of Washington* |
| 11:20 am | **Framework for defining the scope of cumulative adverse effects assessments for offshore wind**<br>Wing Goodale, *Biodiversity Research Institute* |
| 11:35 am | **An ecosystem functioning approach for thinking about cumulative impacts**<br>Steven Degraer, *Royal Belgian Institute of Natural Sciences* |
| 11:50 am | **Metapopulation PVA: Developing methods for reducing uncertainty in impact assessments**<br>Julie Miller, *Marine Scotland Science* |
| 12:05 pm | *Panel Q&A and Discussion* |

## Tuesday, November 17

| ***Session 2: European Efforts to Understand Cumulative Impacts from Offshore Wind.*** *Moderator: Sophie Hartfield Lewis, Ørsted*<br>10:30 am – 12:00 pm EST | |
|---|---|
| 10:30 am | *Introduction* |
| 10:35 am | **Assessing cumulative effects: challenges faced by offshore wind developers**<br>Madeline Hodge, *Ørsted* |
| 10:50 am | **WinMon.BE: The Belgian countrywide research program to understand cumulative impacts of offshore wind development**<br>Steven Degraer, *Royal Belgian Institute of Natural Sciences* |
| 11:05 am | **Offshore wind farms: Cumulative impact assessments in the Netherlands**<br>Astrid Potiek, *Bureau Waardenburg* |
| 11:20 am | **Developing a cumulative effects framework (CEF) for key ecological receptors in relation to offshore wind in the UK**<br>Kate Searle, *UK Centre for Ecology and Hydrology* |
| 11:35 am | *Panel Q&A and Discussion* |
| 12:00 pm | *Break* |

| ***Session 3: Lightning Talks Round 1.*** *Moderator: Matt Robertson, Vineyard Wind*<br>12:15 – 1:30 pm EST | |
|---|---|
| 12:15 pm | **Status of NMFS survey activities impacted by wind development**<br>Andy Lipsky, *NOAA Northeast Fisheries Science Center* |
| 12:20 pm | **Migratory paths of horseshoe crabs in peril due to offshore energy development**<br>John Tanacredi, *Center for Environmental Research and Coastal Oceans Monitoring* |
| 12:25 pm | **Pelagic fish and zooplankton abundance and distribution in the New York Bight**<br>Joseph Warren, *Stony Brook University* |
| 12:30 pm | **Large bony fish information from New York OPA**<br>Jeff Clerc, *Normandeau Associates Inc.* |
| 12:35 pm | *Q&A and Discussion* |
| 12:40 pm | **The BOEM 'RODEO' Program: Lessons learned from environmental monitoring at multiple U.S. offshore wind farms**<br>Kristen Ampela, *HDR, Inc.* |
| 12:45 pm | **Mapping the distribution and habitat use of Atlantic cod spawning aggregations on Cox's Ledge to assess potential impacts of offshore wind development**<br>Rebecca Van Hoeck, *University of North Carolina at Chapel Hill* & Ali Frey, *University of Massachusetts Dartmouth School for Marine Science & Tech.* |
| 12:50 pm | **Multi-scale relationships between marine predators and the distribution of forage fish**<br>Evan Adams, *Biodiversity Research Institute* |
| 12:55 pm | **Benthic habitat and epifaunal monitoring at the Block Island Wind Farm**<br>Zoe Hutchison, *University of Rhode Island* |
| 1:00 pm | *Q&A and Discussion* |
| 1:05 pm | **Expected effects of proposed large scale offshore wind farm implementation of common guillemots (*Uria aalge*) in the southern North Sea**<br>Verena Peschko, *University of Kiel* |
| 1:10 pm | **Protected Species Observer (PSO) detections of North Atlantic Right Whales (NARW): Contributing to science, conservation, and management**<br>Craig Reiser, *Smultea Sciences* |
| 1:15 pm | **Age-based habitat use of humpback whales in the New York Bight and implications for vessel strikes**<br>Julia Stepanuk, *Stony Brook University* |
| 1:20 pm | **Review of night vision technologies for detecting cetaceans at sea**<br>Mari Smultea, *Smultea Sciences* |
| 1:25 pm | *Q&A and Discussion* |

## Wednesday, November 18

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|---|---|
| ***Session 4: Current Knowledge on Cumulative Impacts I.*** *Moderator: Jillian Liner, Audubon New York*<br>10:30 -11:45 am EST | |
| 10:30 am | *Introduction* |
| 10:35 am | **The Vineyard Wind SEIS: Assumptions made in the cumulative impact scenario**<br>Ian Slayton, *Bureau of Ocean Energy Management* |
| 10:50 am | **Cumulative impacts of displacement on seabirds**<br>Stefan Garthe, *Kiel University* |
| 11:05 am | **Cumulative impacts to birds from collisions with offshore wind farms**<br>Aonghais Cook, *British Trust for Ornithology* |
| 11:25 am | *Panel Q&A and Discussion* |
| 11:45 am | *Break* |
| ***Session 5: Current Knowledge on Cumulative Impacts II.*** *Moderator: Ruth Perry, Shell New Energies*<br>11:55 am – 1:30 pm EST | |
| 11:55 am | **Cumulative physical effects of offshore wind energy development on oceanographic processes**<br>Jeff Carpenter, *Institute of Coastal Research, Helmholtz-Zentrum Geesthacht* |
| 12:15 pm | **Cumulative effects of offshore wind on benthic habitats**<br>Drew Carey, *INSPIRE Environmental* |
| 12:30 pm | **Cumulative noise impacts upon fishes (and turtles) from offshore wind construction and operation**<br>Arthur Popper, *University of Maryland & Anthony Hawkins, Loughine Ltd.* |
| 12:50 pm | **Designing studies to detect the ecological impacts of offshore wind development**<br>Elizabeth Methratta, *contractor to NOAA Northeast Fisheries Science Center* |
| 1:05 pm | *Panel Q&A and Discussion* |

## Thursday, November 19

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|---|---|
| ***Session 6: Current Knowledge on Cumulative Impacts III.*** *Moderator: Francine Kershaw, Natural Resources Defense Council*<br>10:30 am – 12:15 pm EST | |
| 10:30 am | *Introduction* |
| 10:35 am | **Decision framework to identify populations that are vulnerable to population-level effects of disturbance**<br>Cormac Booth, *SMRU Consulting* |
| 10:55 am | **Cumulative noise impacts to marine mammals from offshore wind development and operations**<br>Brandon Southall, *Southall Environmental Associates Inc.* & Howard Rosenbaum, *Wildlife Conservation Society* |
| 11:15 am | **Vessel encounter risk model tool**<br>Mary Jo Barkaszi, *CSA Ocean Sciences Inc.* |
| 11:30 am | **Population impacts to bats from wind energy development**<br>Cris Hein, *National Renewable Energy Laboratory* |
| 11:45 am | *Panel Q&A and Discussion* |
| 12:15 pm | *Break* |
| ***Session 7: Lightning Talks Round 2.*** *Moderator: Jenny Briot, Avangrid*<br>12:30 - 1:30 pm EST | |
| 12:30 pm | **Introduction to ICES Offshore Wind Working Group**<br>Andy Lipsky, *NOAA Northeast Fisheries Science Center* |
| 12:35 pm | **A stakeholder driven vision: Regional Wildlife Science Entity for Atlantic offshore wind**<br>Kate McClellan Press, *NYSERDA* |
| 12:40 pm | **The Responsible Offshore Science Alliance (ROSA): Establishing regional research and monitoring for offshore wind and fisheries**<br>Lyndie Hice-Dunton, *Responsible Offshore Science Alliance* |
| 12:45 pm | **U.S. Offshore wind synthesis of environmental effects research**<br>Rebecca Green, *National Renewable Energy Laboratory* |
| 12:50 pm | *Q&A and Discussion* |
| 1:00 pm | **Updating collision risk models to quantify cumulative impacts for endangered birds**<br>Christopher Field, *University of Rhode Island* |
| 1:05 pm | **Analysis and visualization of marine-life data in the context of offshore wind energy development**<br>Marta Ribera, *The Nature Conservancy* |
| 1:10 pm | **Development of monitoring protocols for automated radio telemetry studies at offshore wind energy areas**<br>Pam Loring, *U.S. Fish & Wildlife Service* |
| 1:15 pm | **New technology reduces the probability of vessel strikes on whales – in certain situations all the way to zero**<br>Dave Steckler, *Mysticetus* |
| 1:20 pm | **Ecosystem dynamics: An examination of the relationships between environmental processes, primary productivity, and distribution of species at higher trophic levels**<br>Frank Thomsen, *DHI Group* |
| 1:25 pm | *Q&A and Discussion* |

## Friday, November 20

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|---|---|
| ***Session 8: Designing Studies to Assess Cumulative Impacts.*** *Moderator: Louis Brzuzy, Shell New Energies*<br>10:30 am – 12:25 pm EST | |
| 10:30 am | *Introduction* |
| 10:35 am | **Synthesis of the science: Interactions between offshore wind development and fisheries**<br>Andrew Lipsky, *NOAA Fisheries,* Brian Hooker, *Bureau of Ocean Energy Management,* Annie Hawkins, *Responsible Offshore Development Alliance,* & Lyndie Hice-Dunton, *Responsible Offshore Science Alliance* |
| 10:55 am | **Approaches to understanding cumulative effects of stressors on marine mammals**<br>Peter Tyack, *University of St. Andrews* |
| 11:15 am | **Designing monitoring to detect cumulative impacts and address the confounding variable of climate change**<br>Jon Hare, *NOAA Northeast Fisheries Science Center* |
| 11:35 am | *Panel Q&A and Discussion* |
| 12:05 pm | *Break* |
| 12:10 pm | **Charge and process for working groups**<br>Kate Williams, *Biodiversity Research Institute* |
| 12:20 pm | **Closing Remarks**<br>Kate McClellan Press, *NYSERDA* |
| ***Session 9: Informal Breakout Group Discussions***<br>12:25 pm – 1:00 pm EST | |
| | *Informal breakout group discussions for the seven work group topics:*<br>• Benthos<br>• Fishes and mobile invertebrates<br>• Birds<br>• Bats<br>• Marine mammals<br>• Sea turtles<br>• Environmental change<br>Each group will discuss (1) intended focus/goals of group discussions, (2) resources to inform discussions, and (3) potential timing for winter meetings. |

# Information on Work Group Meetings

## Introduction

Work groups for the *State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts* will focus on identifying key research and coordination efforts for the next 3-5 years that could help improve our understanding of cumulative impacts as the industry progresses in the U.S. There are expected to be seven work groups:

- Benthos
- Fishes and mobile invertebrates
- Birds
- Bats
- Marine mammals
- Sea turtles
- Environmental change

Each work group, led by a technical expert, will meet virtually twice (~Dec 2020/Jan 2021 and Feb/Mar 2021) to identify key research and coordination needs. The outcomes of the seven work groups will be summarized at a final webinar in the spring of 2021 that will be open to all workshop attendees.

## Work Group Product

The main product is a research plan outline that includes brief descriptions from each work group of:

- Priority research studies that could be initiated in the short term to improve our understanding of cumulative biological impacts; these could focus on a range of geographic or temporal scales and types of stressors and receptors
- Other priority efforts that could be initiated in the short term to improve our understanding of cumulative impacts, such as research coordination, data sharing, or technology development
- Longer-term priorities (e.g., information or methodological/technological gaps that may not be addressable in the next 5 years)

## Work Group Membership

Following the plenary workshop sessions in November, workshop participants will be asked to self-select into work groups for winter meetings. Membership may be adjusted to ensure a reasonable group size for discussions based on level of interest and input from technical leads for each work group. A technical expert will lead each work group's efforts with support from a logistical lead and workshop staff.

## Timeline

**November 20, 2020**

*Informal breakout group discussions*

Working group leads will host informal discussions to share their intended group focus and obtain initial input from workshop attendees

**November 2020 – January 2021**

*First Working Group virtual meetings*

Working group leaders review pre-existing data and efforts to identify priorities or conduct research; group members work together to identify key gaps and research/coordination needs to improve our understanding of cumulative impacts.

**January – March 2021**

*Second Working Group virtual meetings*

Working group leaders present draft research and coordination priorities to their group for input.

**April-May 2021**

*Culmination Webinar*

Working groups report back their list of key studies to the full group of all workshop attendees, followed by cross-group synthesis and discussion

## Work Group Descriptions

Work group products are expected to build from existing research, prioritization, and synthesis efforts, such as:

- Offshore wind energy research and cumulative impact frameworks from Europe
- Recent efforts in the eastern U.S. to develop scientific research frameworks to understand the effects of offshore wind development on marine mammals, sea turtles, birds, and bats
- December 2020 special issue of *Oceanography* focused on understanding the effects of offshore wind energy development on fisheries

The seven work groups are:

**Benthos -** Group discussion may focus on how best to understand the potential long-term effects of offshore wind development on benthic communities, including changes in substrate availability, community composition, and ecosystem structure and function.

**Fishes and mobile invertebrates -** Group discussion may focus on the effects of aquatic noise (both sound pressure and particle motion), electromagnetic fields from buried cables, and/or changes in habitat complexity, which in turn could alter food availability, shelter, and spawning habitat, among other effects.

**Birds -** Discussions may focus on how best to improve our understanding of cumulative impacts from offshore wind to birds in relation to displacement and barrier effects, collision mortality, and habitat change. This may include consideration of known and suspected taxon-specific differences in vulnerability to these stressors.

**Bats -** Discussions may focus on how best to improve our understanding of cumulative impacts from offshore wind to bats, including addressing gaps in our knowledge of bat abundance, distribution, and behavior in the offshore environment, and the potential for collision-related impacts.

**Marine mammals -** Discussions may focus on how best to improve our understanding of cumulative impacts from offshore wind to marine mammals in relation to noise impacts, displacement and behavioral change, vessel collision risk, and/or changes to physical habitat and resource availability.

**Sea turtles -** Discussions may focus on how best to improve our understanding of impacts to sea turtles from offshore wind, including noise impacts, electromagnetic fields, vessel interactions, and/or changes to physical habitat and resource availability.

**Environmental change -** Discussion topics could include the potential for offshore wind development to influence water column stratification and cold pool mixing, local wind patterns, wave generation, tidal amplitudes, and/or dynamics of suspended particles and bedload transport of sediment.

# Lightning Talk Abstracts

Abstracts are in alphabetical order by first author's last name

## Multi-scale relationships between marine predators and the distribution of forage fish

*Adams, E. (evan.adams@briloon.org)[1], Friedland, K.[2], Gilbert, A.[1], Goetsch, C.[1], Goyert, H.[3], Gulka, J.[1], Stenhouse, I.[1], Williams, K.[1], Winship, A.[3]*

[1] Biodiversity Research Institute; [2] NOAA Northeast Fisheries Science Center; [3] NOAA National Centers for Coastal Ocean Science

The trophic structure of marine ecosystems is complex, owing in part to dynamic spatiotemporal variability. To better understand the combined effects of environmental changes and biological interactions on marine species, we are conducting a study of the multiple scales at which forage fish influence marine predators. Forage fish distributions and aggregations are quantified by combining observations from NOAA bottom trawl surveys and digital aerial surveys. These data from the Northeast U.S. Continental Shelf will be used to quantify how forage fish populations affect key seabird predators like Northern Gannets, Red-throated Loons, and Long-tailed Ducks at three scales:

- individual movements and habitat use, where forage fish availability will be connected to predator movements using behavioral models derived from satellite telemetry data;
- seasonal changes in predator distribution and abundance, where integrated modeling techniques will be used to combine data from multiple survey types; and
- long-term population trends, where archival survey data for predator and prey species will be combined to determine temporal correlations in areas with high survey effort.

This project is ongoing; the current focus is on forage fish availability estimation and seabird movement modeling. We will discuss our current approach to forage fish data synthesis using spatially explicit distribution and group size models, and our implementation of Hidden Markov models to estimate seabird movement. Using these techniques to elucidate biotic connections is important to understanding how anthropogenic changes to marine ecosystems—particularly from offshore wind development—could affect predators in multifaceted ways.

## The BOEM 'RODEO' Program: Lessons learned from environmental monitoring at multiple U.S. offshore wind farms

*Ampela, K. (Kristen.ampela@hdrinc.com)[1], Khan, A.[1]*

[1] HDR, Inc.

The purpose of the BOEM-sponsored Real-time Opportunity for Development Environmental Observations (RODEO) Program is to gather real-time data during construction and operation of offshore wind farms (OWF) at various locations in the U.S. to help assess environmental impacts of current—and planned—OWF facilities. Starting in 2015, a four-year monitoring study was conducted at the Block Island Wind Farm

(BIWF) off Rhode Island, the first commercial wind farm in the U.S. A suite of environmental data was collected, including underwater and airborne noise measurements during construction and initial operations; turbine scour; seafloor disturbance and recovery rates; benthic community abundance and diversity, and epifouling of turbine foundations. Valuable lessons learned and data gathered at BIWF have informed and refined environmental monitoring approaches for future U.S. OWF developments, including improved sensor placement design; expansion of metocean data collection and corrosion monitoring, and increased focus on underwater noise monitoring during construction to better understand potential impacts on marine mammals, sea turtles, and fish. The RODEO Program provides an important framework to align and integrate results from environmental studies of OWFs in multiple regions, involving different design and construction approaches, in a variety of benthic habitats and sediment types. The understanding and insights gained from the Program will also help BOEM to identify, reduce, and mitigate environmental risks in the future, and significantly increase the efficiency of BOEM's regulatory review process for OWF development in the U.S.

## Large bony fish information from NY OPA

*Clerc, J. (jclerc@normandeau.com)[1], Robinson Willmott, J.[1], Lampman, G.[2]*
[1] Normandeau Associates Inc; [2] NYSERDA

NYSERDA commissioned Normandeau-APEM to provide 3 years of seasonal aerial digital surveys over the entire offshore planning area. Although surveys were designed to capture information on birds, marine mammals, turtles and cartilaginous species, they also inadvertently captured information on some large bony fish species, specifically mahi-mahi, sunfish, billfish and tuna species, some of which showed preferences with regard to distance from shore, ocean depth, and/or seasonality. Normandeau would be delighted to share this information with the workshop attendees.

## Updating collision risk models to quantify cumulative impacts for endangered birds

*Field, C. (christopher.field@uconn.edu)[1], Loring, P.[2], Gerber, B.[3]*
[1] University of Rhode Island; [2] Division of Migratory Birds, U.S. Fish and Wildlife Service, [3] Department of Natural Resources Science, University Of Rhode Island

Developing a decision support framework for the potential impacts of offshore wind on wildlife requires addressing several challenges. These include propagating and communicating multiple sources of uncertainty, interpreting models for non-specialists, and the need for agility in the face of shifting data availability. We will discuss our recent efforts to address these challenges as we develop an online support tool for quantifying the impacts of offshore wind on endangered birds. We will discuss specific challenges to adapting recent European efforts for U.S.-based policy, including differences in the availability of key data sources. We will highlight our efforts to integrate data from the Motus wildlife tracking network and quantify cumulative impacts across offshore projects. We will also discuss the generalizability of our work, including key similarities

and differences between our work and other efforts to model and communicate risk associated with offshore wind.

## U.S. offshore wind synthesis of environmental effects research

*Gorton, A.[2], Green, R. (Rebecca.green@nrel.gov)[1], Harker-Klimes, G.[2], Hein, C.[1], Straw, B.[1]*
[1] National Renewable Energy Laboratory; [2] Pacific Northwest National Laboratory

At the direction of the Department of Energy, Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL) are partnering on the U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) project. The multi-year collaborative effort will facilitate knowledge transfer for offshore wind (OSW) research around the world to synthesize key issues and disseminate existing knowledge about environmental effects, inform applicability to U.S. waters, and prioritize future research needs. Research related to monitoring and mitigating impacts from OSW development on wildlife, habitats, and related environmental processes will inform environmental research prioritization among stakeholders, reduce redundancy among stakeholder group activities, and catalyze solution development. The outcomes of this project will build relationships among various OSW environmental stakeholders to support strategic research efforts by increasing communication, encouraging collaboration, and reducing redundancy. Where feasible, work products will identify key areas where misinformation persists and issues that have been thoroughly studied, are well understood, and can be considered low priority or resolved.

This presentation will include: project impetus, goals, and objectives; stakeholder outreach and engagement efforts; research topics and prioritization; project products and outcomes; and dissemination methods.

## The Responsible Offshore Science Alliance (ROSA): Establishing regional research and monitoring for offshore wind and fisheries

*Hice-Dunton, L. (lyndie@rosascience.org)[1]*
[1] Responsible Offshore Science Alliance

The Responsible Offshore Science Alliance (ROSA) is a partnership formed by fishermen and offshore wind leaders, in collaboration with US federal and state management experts to enhance scientific understanding necessary to support the coexistence of wind energy development and sustainable fisheries. Formed in early 2019, ROSA provides for and advances regional research and monitoring of fisheries and offshore wind interactions through coordination and cooperation. Modelled after successful partnerships in Europe and elsewhere, ROSA's mission is to advance our understanding of interactions in US state and federal waters. The organization's goal is to increase salient and credible data on fisheries and wind development and improve our knowledge on of the effects of wind energy development on fisheries and ocean ecosystems. ROSA will maximize public-private partnerships to enhance understanding of the ocean

environment that fisheries and offshore wind energy activities occupy, through rigorous and unbiased science and research efforts. Specifically, ROSA aims to: identify regional research and monitoring needs; provide a forum for coordinating existing programs; advance regional understanding through collaboration, partnerships, and cooperative research; facilitate and improve standardization and access to data; administer research; and disseminate research and communicate findings. The presentation will focus on an overview of ROSA's formation, progress to date, and future actions of the organization.

## Benthic habitat and epifaunal monitoring at the Block Island Wind Farm

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As part of the RODEO Program, a three-year benthic habitat and epifouling monitoring effort took place at Block Island Wind Farm (BIWF) between late-2016 and late-2019. The aim of the study was to observe and quantify near-field spatio-temporal changes in the seabed, focusing on the sediment grain size, organic enrichment and benthic macrofaunal communities present. Efforts were later extended to characterize the epifaunal growth on the BIWF turbine foundation structures. On the structure, the epifaunal communities were dominated by the blue mussel, *Mytilus edulis*. Other species of note were the coral, *Astrangia poculata* and invasive tunicate, *Didemnum vexillum* and an abundance of black sea bass, *Centropristis striata*. Within the turbine foundation footprints, particularly at Turbine 1, mussel aggregations had formed. In areas of dense mussel aggregations increased sediment fines and organic enrichment were evident. Within the 30-90 m area from the center of the turbine, no specific gradients of change with distance from the structure were detected in sediment grain size or organic enrichment. The macrofaunal composition and characteristics were variable between turbines and years. Turbine 1 was more distinct from Turbine 3 and 5 in macrofaunal community characteristics. Within the Turbine 1 study area, mussels had become more abundant and there were few, but distinct areas of strong change associated with mussel presence. The results suggest that future expansion of offshore wind farms across the east coast continental shelf should consider the cumulative benthic modification where similar jacket foundation types are installed.

## Status of NMFS survey activities impacted by wind development

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TBD

## Introduction to ICES Offshore Wind Working Group

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## Development of monitoring protocols for automated radio telemetry studies at offshore wind energy areas

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We are developing guidance for using automated radio telemetry to monitor bird and bat movements at offshore wind energy areas throughout the U.S. Atlantic with funding from NYSERDA. This collaborative project will include: 1) a monitoring framework for pre and post-construction tracking studies with a focus on federally threatened or endangered terns and shorebirds; 2) a guidance document for co-locating and operating receiving stations on offshore wind turbines and buoys; 3) a free online tool to optimize site-specific study designs at offshore wind projects; 4) a simulation study to estimate detection probability for focal species; and 5) a framework to coordinate data from tracking efforts throughout the U.S. Atlantic with the Motus Wildlife Tracking System. We are developing study products with extensive stakeholder input, including a Project Advisory Committee with representatives from industry, government, and research sectors. In 2021, we will hold a series of workshops to refine study products and work with developers to field test new technology at lease areas. The overarching goal of this effort is to help develop and coordinate automated radio telemetry studies for monitoring avian and bat movements through individual lease areas and the broader U.S. Atlantic offshore region using the best available science. Final study products are anticipated in early 2022.

## Expected effects of proposed large scale offshore wind farm implementation on Common Guillemots (*Uria aalge*) in the southern North Sea

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As climate change is rapidly progressing, the pressure for governments to massively reduce greenhouse gas emissions is stronger than ever. The German government plans to implement 40 GW of offshore wind power in the German Exclusive Economic Zone (EEZ) by 2040. As one of the most numerous seabird species in the world, the common guillemot (*Uria aalge*) is prone to interfere with offshore wind farms (OWF). To quantify the possible conflict between guillemot occurrence and current plans of the German government regarding implementation of large scale OWFs, we used a long-term dataset on the distribution and abundance of guillemots in combination with recent estimates of the OWF avoidance by guillemots in German waters. If the current plans are realized, the footprint of the installed OWFs would cover 17% of the German EEZ. Because guillemot density is significantly reduced inside the OWFs and within a radius of 9 km around the OWFs, the 'affected area' would equal 53% of the German EEZ. In total, 54,000

(i.e. 60%) of the guillemots occurring in the German North Sea in autumn are using the 'affected area'. As guillemot density was reduced by 49% inside the 'affected area', 30% of the German guillemot population in autumn would experience habitat loss. This clearly illustrates the possible threat for guillemots in the southern North Sea if the current plans of the German government are implemented. The estimates provided here are essential for the development of a sustainable scenario to reduce the human CO2 footprint while protecting biodiversity.

## A stakeholder driven vision: Regional Wildlife Science Entity for Atlantic offshore wind

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Starting at the inaugural State of the Science Workshop in 2018, stakeholders expressed the importance of developing a multi-sectoral regional science entity to support research and monitoring on wildlife and offshore wind energy. The effort was further advanced through a series of workshop hosted by the New York State Energy Research and Development Authority (NYSERDA), the Special Initiative for Offshore Wind and the Massachusetts Clean Energy Center (MassCEC). Building from these early efforts, a strong stakeholder engagement process was advanced to develop the current vision for a Regional Wildlife Science Entity (RWSE) for Atlantic offshore wind. The process has been led by a "Coordinating Group", or representative group of stakeholders including NYSERDA, MassCEC, the Bureau of Ocean Energy Management (BOEM), the National Oceanic and Atmospheric Administration (NOAA), Shell, Equinor, the Natural Resources Defense Council (NRDC), and the National Wildlife Federation (NWF). Since 2019, the effort has engaged with stakeholders through meetings, workshops, and interviews to better understand the need for coordinated regional science, define the scope and identify potential organizational designs, which are documented in the RWSE's Organizational Vision. In late 2020, the Coordinating Group has been gathering letters of support and will solicit proposals for a fiscal agent and director through a Request for Qualifications (RFQL) from NYSERDA.

## Protected Species Observer (PSO) detections of North Atlantic Right Whales (NARW); Contributing to science, conservation, and management

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Offshore wind development in the US Atlantic Ocean relies on protected species observers (PSOs) to conduct dedicated monitoring and mitigation of all vessel operations. These efforts entail a great deal more than simply satisfying a suite of regulatory requirements. In particular, numerous industry operators have expanded their baseline PSO monitoring and mitigation programs to add considerable value to North Atlantic right whale (NARW) conservation efforts through data sharing and reporting measures. Detections of NARW by PSOs are significant events that begin long before passionate PSOs mobilize to vessels, and they extend well beyond completion of a survey. Countless hours are spent vetting, hiring, training, and preparing PSOs for the moment when they detect a NARW. PSOs are fortified with a multitude of tools and technologies to assist their real-time assessment of appropriate mitigation measures. These

tools include Mysticetus' data collection software, configured within a regional network of project vessels to allow for automated sharing of detections between vessel PSO teams, as well as automated NARW text and email alerts for onshore project managers. PSOs document all NARW with high definition cameras. Detection data are shared immediately with the NOAA Right Whale Sighting Advisory System via the Whale Alert smartphone application. Photos are shared with NOAA's Northeast Fisheries Science Center and the New England Aquarium. These proactive efforts are made to ensure – first and foremost – all NARW encounters are mitigated, but also to contribute to the overarching goal of advancing NARW science, conservation, and management for the greater good.

## Analysis and visualization of marine-life data in the context of offshore wind energy development

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In the past few years, there has been an acceleration in the interest for the development of commercial offshore wind energy sites along the US Atlantic seaboard, with over 4.5 million acres of ocean habitat off the east coast of the US either already leased (1.75M) or formally in the process of being considered for leasing (2.75M). The Nature Conservancy wants to ensure that siting, construction, and operation of wind development offshore is done with the environment in mind, considering key habitats and species. We believe it is critical to provide the best scientific information to stakeholders to guide the planning and review process. However, stakeholders reviewing Environmental Impact Assessments for wind development projects either don't have access to all the needed information or the capacity to quickly review each submission within the time allowed. Regional data portals compile the best available regional data, but reviewing and interpreting all appropriate information is often an overwhelming task. Also, stakeholders can only view each dataset in isolation, without any interpretation of what it means in the context of other species and processes in the region. TNC is developing a peer-reviewed decision support tool to contextualize siting of wind energy projects, and to avoid and monitor potential negative environmental impacts. By summarizing important natural resources for an area, users can identify potential red flags in the development and operation of wind energy offshore.

## Review of night vision technologies for detecting cetaceans at sea

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Data are sparse on specific model, specification, cost and at-sea effectiveness of vision-enhancing devices for detecting cetaceans during darkness. We identified/evaluated/compared 15 specific vision-enhancing devices used/useful to meet U.S. Atlantic regulatory requirements for marine mammal mitigation/monitoring during darkness for Ørsted and Deepwater Wind offshore wind development activities in 2017-19. Evaluation focused on cetacean detection at distances of 200, 500 and 1000 m from a vessel. We compiled available literature, personal communications with experts, our own in-field results and internet searches. Results indicate that for regulated zones <200 m in radius, recently used specific hand-held infra-red (IR) and hand-held light-enhancing devices are considered reasonably effective. At 200-500+ m, more expensive yet reasonably priced mounted IR devices providing automatic detection software,

image stabilization, remote display, and/or mitigation zone delineation improve objective mitigation decision-making and alleviate observer eye strain of handheld devices. Multiple camera use and video/still image review capability improve sighting effectiveness and reduce false negative indications. Device performance is influenced by weather conditions (fog, rain). Using mounted IR cameras we detected whales and delphinid groups 1+ km away in good conditions. Newly available devices should be reviewed on a continuum to identify improvements/affordability. Testing of night/low-light vision devices via controlled systematic studies is needed for regions where offshore wind development and operations occur during low-light conditions, focusing on seasons and areas where sample sizes of cetacean visual detections can be maximized. Compilation and statistical comparisons of Atlantic sightings data is highly recommended to examine robustness/effectiveness of devices under various conditions.

## New technology reduces the probability of vessel strikes on whales – In certain situations all the way to zero

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Recent advances and cost reductions in internet technology has resulted in most medium-to-large working vessels on the ocean possessing internet connectivity 24x7. These systems have already been used by Protected Species Observers (aka Marine Mammal Observers, or PSO, MMO) in the Atlantic working on mitigation of anthropogenically impactful activities such as wind farm construction. Specifically, PSO tasks include monitoring for protected species including whales, dolphins and sea turtles, and directing appropriate mitigation actions to protect animals when detected. Previously such internet systems were mostly used for simple tasks such as email of status reports, Dropbox file transfer, etc. Here we present a new interconnectivity system, The Mysticetus Sharing Network, that leverages near-universal internet connectivity to instantly share and map animal sightings amongst all participants, including audible alerts, text and email notifications to all stakeholders, and collision prediction and automated avoidance recommendations. We also present one example where the use of this system reduced the probability of vessel strike on two specific North Atlantic Right Whales to absolute zero. According to our analysis, these types of situations where the Mysticetus Sharing Network diverts vessels away from whales sighted by others occur approximately once a month. We will also present extensions to the Mysticetus Sharing Network that include the tracking and sharing of information from other data sources increase PSO situational awareness. This includes PAM-enabled drones and moored buoys from Woods Hole, and Rutgers and Dalhousie Universities; instant integration of animal sightings from select non-profits such as the New England Aquarium and Center for Coastal Studies; and (coming soon) instant integration from various external data sources such as sea turtle sighting networks and stranding networks.

## Age-based habitat use of humpback whales in the New York Bight and implications for vessel strikes

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There is an ongoing Unusual Mortality Event (UME) of humpback whales (*Megaptera novaeangliae*) along the eastern seaboard of the US, and juvenile whales represent a high

proportion of large whale strandings in this region. In the New York Bight, juvenile humpback whales have been observed lunge feeding on Atlantic menhaden (*Brevoortia tyrannus*) close to shore, but it is unclear whether there are age-specific patterns of habitat use and foraging behavior in humpbacks. We compare the habitat use and foraging behavior of juvenile and adult humpback whales in the New York Bight, and examine implications for the vulnerability to anthropogenic impacts (e.g., vessel strikes, wind farm development). We conducted boat-based surveys in the NYB from 2018-2020 and conducted focal follows to identify individual whales, document foraging behavior, and obtain morphometric measurements using a DJI Phantom 4 Pro+ Unmanned Aerial Vehicle. We determined animal lengths and age class from morphometric data and compared the sightings of adult vs. juvenile whales based on distance from shore, foraging behavior, and age-class composition. Whales foraging in nearshore waters were exclusively juveniles that were surface feeding, while both juveniles and adults foraged cooperatively in offshore waters. The nearshore habitat use and surface foraging behavior of juvenile humpback whales may make them particularly vulnerable to anthropogenic impacts in nearshore waters.

## Migratory paths of horseshoe crabs in peril due to offshore energy development

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*Limulus polyphemus*, the North American Horseshoe Crab, for over 445 million years has migrated ashore along the Atlantic coast with amazing site fidelity to numerous breeding beaches. These migratory tides of HSCs during the peak breeding season of May through September each year have provided their eggs to support millions of shorebirds on their annual and synchronized migration each year as well. The potential impacts from offshore energy development to these living fossils' consistent fecundity, to their nearshore breeding beaches and to the adjacent nearshore lands has never been investigated nor adequately assessed.

## Ecosystem dynamics: An examination of the relationships between environmental processes, primary productivity, and distribution of species at higher trophic levels

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The state of New York is committed to pursuing development of 9,000 MW of offshore wind energy by 2035. As part of planning and assessment related to this effort, NYSERDA has developed a Master Plan and undertaken several field and desktop studies to reduce risk and inform and improve siting and authorization processes. Here we present a NYSERDA project to examine the relationships between environmental processes, primary productivity, and distributions of species at higher trophic levels to help predict animal use patterns at differing temporal scales in the New York Bight. This effort will evaluate data coverage, sensitive variables, data gaps, and will pave the way for comparative assessments of the power of available ecosystem data to predict wildlife distribution and movement during all stages of wind farm development.

This collaborative project is developing hydrodynamic models based on data about the distribution of oceanographic characteristics in the New York Bight and applying these models

and observations of taxa to develop dynamic habitat models that show temporally changing predictions of use of areas by loggerhead sea turtles, fin whales, red-throated loons, and northern gannets. The dynamic habitat models for red-throated loons and fin whales will further be used as a driver in agent-based models to predict movements of individuals in the New York Bight. This approach to modeling allows for consideration of dynamic environmental preferences and can be adjusted to consider future conditions in addition to assessing average expectations.

## Mapping the distribution and habitat use of Atlantic cod spawning aggregations on Cox's Ledge to assess potential impacts of offshore wind energy development

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Atlantic cod (*Gadus morhua*) is an ecologically, economically, and culturally important groundfish species that has been historically overexploited. Many studies have described the spawning dynamics of cod in other areas, but uncertainty remains concerning cod in Southern New England. Several aspects of cod spawning behavior, such as forming large, dense spawning aggregations, increases their vulnerability to disturbance. Offshore wind energy development may impact cod through loss of essential spawning habitat and disruption of spawning behavior. Through the use of interdisciplinary methodologies, this study aims to map the spatiotemporal distribution of spawning and track life history parameters of Atlantic cod in Southern New England, while serving as a pre-construction baseline study for characterizing interactions with planned offshore wind farms. Beginning in November 2019, we tagged spawning cod with telemetry transmitters and deployed a receiver array in and around the South Fork wind area. An autonomous glider, carrying a telemetry receiver and hydrophone to record cod spawning vocalizations, swam an approximately 1,500 km2 area over Cox's Ledge. Additionally, historical passive acoustic recordings were reviewed for spawning activity in this area. Fisheries dependent biological samples were collected to track growth, maturity, and the onset of spawning. Preliminary results suggest spawning spans from November to March, with high residence on Cox Ledge, and some regional spawning outside the area. Combined results over the three year study will fill knowledge gaps regarding the spawning dynamics and habitat usage of Atlantic cod in Southern New England and facilitate assessment of offshore wind energy impacts.

## Pelagic fish and zooplankton abundance and distribution in the New York Bight

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Ship-based echosounder surveys have been conducted seasonally in the New York Bight over the past three years to monitor pelagic aggregations of fish and zooplankton. By using multiple acoustic frequencies, we can often identify aggregations of fish or zooplankton and quantify

their distribution and relative abundance. Trawl and net tows provide information on the species present in the region during each cruise. Spatial and temporal variability in these data will be discussed as well as how some aggregations may be related to environmental parameters or bathymetric features.

# Glossary of Terms

**Abundance** – The number of animals in a biological population. Different from *relative abundance* (see below).

**Aerial survey** – A method of systematic data collection (such as species abundance and distribution) from the air via airplane or unmanned aerial vehicle (UAV). Surveys may be conducted with visual observers on board (visual aerial survey) or by taking video or photo imagery to capture presence of wildlife (digital aerial surveys).

**Anthropogenic -** Originating in human activity.

**Artificial reef effect** – Attraction of marine species to manmade underwater structures that represent new habitat (e.g., hard substrate) on which algae and invertebrates can grow.

**BACI** – Before-After-Control-Impact. An experimental design for studying the effects of a stressor. In this design, one or more control sites are paired with one or more impact sites (i.e., sites where the stressor will operate). These are monitored both before and after the start of the stressor. The paired design allows changes due to the stressor (which should affect only the impact site) to be distinguished from background changes (which should affect both control and impact sites). Control sites must be carefully chosen to ensure they are physically and ecologically similar to impact sites but are located outside the zone of potential impacts.

**BAG** – Before-After-Gradient. An experimental design for studying the effects of a stressor such as displacement. In this design, monitoring is conducted pre- and post-construction in the wind farm itself, as well as a buffer area around the wind farm, to assess possible relationships between impact and distance from the wind farm. Buffer size must be carefully chosen to ensure it encompasses the full zone of potential impacts. This study design allows for non-linear relationships, incorporation of some types of environmental covariates, and a more informative assessment of effect size than BACI designs.

**Baseline condition -** The prior state or situation used as a reference when determining effect.

**Baseline study** – A baseline study is the initial collection of data to allow comparison with subsequently acquired data. Collecting baseline data allows potential impacts of a project to be assessed and/or monitored.

**Barrier effects** – The impacts on animals due to obstacles to movement (such as increased energetic requirements to fly around, rather than through, a wind facility).

**Benthic** – Relating to or occurring at the bottom of a body of water, including sediments on the ocean floor, as well as animals and plants living on the ocean floor (e.g., benthos).

**BMP** – Best Management Practice.

**BOEM** – Bureau of Ocean Energy Management.

**Cold pool mixing** – Cold waters that enter the Mid-Atlantic Bight from the north form a layer at the bottom of the water column; in the fall and winter, the cold pool mixes with the surface layers, bringing nutrient-rich waters to the surface and fueling primary productivity.

**Community** – A naturally occurring group of species interacting and occupying a habitat.

**COP** – Construction and Operations Plan for offshore wind projects (document is submitted by an offshore wind developer to BOEM as part of the development process).

**Cumulative Impacts** – The effect of an anthropogenic stressor on the environment, adding to, or interacting with, other impacts, on a similar temporal and/or spatial scale. For the purposes of this workshop, discussion focuses explicitly on cumulative impacts from offshore wind energy development, while recognizing that other anthropogenic stressors also contribute to the status of affected populations and ecosystems.

**Density** – The number of a specified organism per unit area.

**Displacement** – When animals adjust their habitat use, such as foraging or breeding, due to a new feature or disturbance, causing effective habitat loss.

**Disturbance** – Any discrete event that has adverse effects upon individual animals, ecosystems, communities, or population structures, and changes resources, patterns of habitat use, or the physical, chemical, or biotic environment.

**Ecosystem** – A biological community of plants and wildlife and their physical environment.

**Effect** – A change caused by a stressor that is a departure for a prior state, condition, or situation (e.g., the baseline condition).

**Electromagnetic field (EMF)** – The field of electric and magnetic forces from underwater cables, which can potentially cause behavioral effects in species that enter the field and are electro- or magneto-sensitive.

**Endangered Species Act (ESA)** – U.S. legislation passed in 1973 designed to protect critically imperiled species from extinction.

**Energetics** – The energy-related properties of animals. Animals have energy budgets, in which they must take in sufficient energy to perform necessary activities, such as foraging, reproducing, and migrating. Energetic impacts, or disruptions to these energy budgets, may have short- or long-term influences on individual survival or reproductive success.

**Environmental Impact Statement** – A document required by the 1969 National Environmental Policy Act for certain actions, including proposed offshore wind development, which describes the positive and negative environmental effects of a proposed action.

**Exposure** – Contact or co-occurrence between stressor and a receptor.

**Food web** – A system of interconnected or interdependent food chains.

**Forage fish** – Abundant small schooling fish species that occupy a key role in the marine food web, transferring energy from lower to higher trophic levels.

**Geophysical surveys** – Exploratory surveys that use reflected sound waves to assess the ocean bottom or subsurface sediments, usually for mineral exploration or to assess a prospective construction site.

**GW** – Gigawatt.

**Harass** – an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering.

**Injury** – any tissue damage and analogous physiological effects resulting from an exposure involving an anthropogenic source.

**Impact** – A biologically significant effect that reflects a change whose direction, magnitude and/or duration is sufficient to have consequences for the fitness of an individual or population.

**Marine Mammal Protection Act (MMPA)** – U.S. law implemented to prevent marine mammal species and population stocks from declining beyond the point where they ceased to be significant functioning elements of the ecosystems of which they are part. This Act provided the initial foundation for the assessment, regulation, and mitigation of sound exposure.

**Marine spatial planning** – A process that brings together ocean stakeholders to share information, allowing for more coordinated ecosystem management and development decisions for the offshore environment.

**MW** – Megawatt.

**Nacelle** – The structure that sits atop the tower of a wind turbine and houses key components, including the gear box and generator.

**National Environmental Policy Act** – A U.S. law that requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions.

**NOAA** – National Oceanic and Atmospheric Administration.

**Oceanography** – The science of the geological, chemical, and physical properties of the ocean.

**OCS** – Outer Continental Shelf.

**Permanent Threshold Shift** – Irreversible hearing loss caused by exposure to sound, in which animals' ability to hear certain frequencies and decibel ranges is permanently impaired even following a period of recovery subsequent to exposure.

**Physiology** – The functions and activities of a living organism or its body parts; includes physical, biological, and chemical phenomena.

**Pile driving** – The process by which a monopile wind turbine foundation is driven into the seabed during construction.

**Plankton** – Small organisms that float in the ocean, including phytoplankton (microscopic plants that produce energy from the sun) and zooplankton (tiny animals, including small crustaceans and the eggs and larvae of larger animals).

**Population Consequences of Disturbance (PCOD)** – A framework designed to explicitly link individual-level effects of anthropogenic disturbance to cumulative impacts on marine populations. It includes modeling how exposure to stressors affects individual behavior and health, how variations in health affects individual vital rates, and resulting potential population-level effects of anthropogenic disturbance.

**Population viability analysis** – Species-specific method of risk assessment that involves estimating the probability that a population will persist in an environment, given its demographic parameters, environmental stochasticity, and other variables. Can be used to inform conservation and management actions by assessing a population's sensitivity to specific stressors or demographic rates.

**Power analysis** – Analytical methods that can be used to inform study designs to ensure a high probability of detecting biologically significant effects (for example, by allowing researchers to predict the sample size required in a research study to detect an effect of a given size with a given degree of confidence).

**Productivity** – The rate of generation of new biomass in an ecosystem. Primary productivity is the creation of energy from sunlight (photosynthesis) by plants and algae that form the basis of the food chain.

**Receptor** – natural resources (such as any living organism or the habitat which supports such organisms) that could be adversely affected by an environmental stressor.

**Relative abundance** – How common a species is relative to others in a certain location, or how common a species is in a given location relative to other locations.

**Sound** – a pressure wave that passes through air or water, and is defined by its frequency (pitch), intensity (loudness), and duration.

**Sound Exposure Level** – A measure of energy that takes into account both received level and duration of exposure, allowing sound exposures of different durations to be related to one another in terms of total acoustic energy.

**Stressors** – Physical, chemical, or biological factors that impact the health and productivity of a species or ecosystem.

**Susceptibility** – factors intrinsic to individuals (e.g., their physical, developmental, and physiological state and behavior) that make them prone (or more prone) to adverse outcomes given exposure to a stressor.

**Telemetry** – The measurement of location data and remote transmission of data (e.g., via radio, satellite) to a monitoring station. Used to track movements of individual animals.

**Temporary Threshold Shift** – Temporary hearing loss caused by exposure to sound, in which animals may have impaired hearing at certain frequencies and at certain decibel ranges for a period of time (hours, days, weeks) following exposure, and from which their hearing recovers to baseline levels.

**Threshold** – A sound (or other stimuli) level that must be exceeded for a physical, physiological, or behavioral reaction or response to occur.

**TRL** – Technology Readiness Level. Metric used by the Department of Energy to assess the maturity level of developing technologies.

**Vulnerability** – The capacity for an individual, population, or species to be negatively affected by a stressor, which arises from a combination of intrinsic factors associated with an organism's susceptibility, and factors related to exposure (duration, timing, frequency, intensity, etc.).