Stakeholder Workshop: Scientific Research Framework to Understand the Effects of Offshore Wind Energy Development on Birds and Bats in the Eastern United States

Workshop Summary | Report Number 20-26 | September 2020

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

NYSERDA's Promise to New Yorkers:

NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Mission Statement:

Advance innovative energy solutions in ways that improve New York's economy and environment.

Vision Statement:

Serve as a catalyst – advancing energy innovation, technology, and investment; transforming New York's economy; and empowering people to choose clean and efficient energy as part of their everyday lives.

Cover Image Courtesy Jonathan Fiely

Stakeholder Workshop: Scientific Research Framework to Understand the Effects of Offshore Wind Energy Development on Birds and Bats in the Eastern United States

Building Energy Exchange, March 4–6, 2020
Workshop Summary

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Kate McClellan Press
Project Manager

Prepared by:

Biodiversity Research Institute

Portland, ME

Julia Gulka
Marine Biologist

Kate Williams
Wildlife and Renewable Energy Program Director

NYSERDA Report 20-26 NYSERDA Contract 118972 September 2020

Notice

Acknowledgements

The workshop convener (Kate McClellan Press, NYSERDA) and workshop organizers (Kate Williams and Julia Gulka, Biodiversity Research Institute) would like to thank all workshop participants for their thoughtful involvement in discussions and for their input on an earlier draft of this report. Particular thanks are also due to speakers who presented at the workshop; to the workshop planning committee, including David Allen and Sally Yannuzzi (North Carolina Wildlife Resources Commission), Scott Johnston and Caleb Spiegel (U.S. Fish and Wildlife Service Migratory Bird Program), Susi von Oettingen (U.S. Fish and Wildlife Service Endangered Species Program), David Bigger (Bureau of Ocean Energy Management), Jillian Liner (Audubon New York), Genevra Harker-Klimeš (Pacific Northwest National Laboratory); and to the facilitation team, including Andrew Farnsworth (Cornell Lab of Ornithology) and Pat Field (Consensus Building Institute). We would also like to thank the Building Energy Exchange for hosting the meeting.

Preferred Citation

New York State Energy and Research Development Authority (NYSERDA). 2020. "Stakeholder Workshop: Scientific Research Framework to Understand the Effects of Offshore Wind Energy Development on Birds and Bats in the Eastern United States, Building Energy Exchange, March 4-6, 2020," NYSERDA Report Number 20-26. Prepared by Julia Gulka and Kate Williams, Biodiversity Research Institute, Portland ME. nyserda.ny.gov/publications

Table of Contents

List of Tables

Acronyms and Abbreviations

ADLS	Aircraft Detection Lighting System
AMAPPS	Atlantic Marine Program for Protected Species
BACI	Before-After-Control-Impact experimental design
BAG	Before-After-Gradient experimental design
BMP	Best Management Practice
BOEM	Bureau of Ocean Energy Management
BRI	Biodiversity Research Institute
CBI	Consensus Building Institute
COP	Construction and Operations Plan
CRM	Collision Risk Model
DOE	U.S. Department of Energy
DRIP	Data Rich, Information Poor (i.e., as coined in Wilding et al. 2017)
EIS	Environmental Impact Statement
ESA	Endangered Species Act
E-TWG	Environmental Technical Working Group for wildlife and offshore wind energy development
EU	European Union
FAA	Federal Aviation Administration
MassCEC	Massachusetts Clean Energy Center
NEPA	National Environmental Policy Act
NEXRAD	Next Generation Radar, also known as WSR-88D weather surveillance radar
NGO	Non-governmental organization
NCCOS	NOAA National Centers for Coastal Ocean Science
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
ORJIP	Offshore Renewables Joint Industry Programme
OSW	Offshore Wind
Q&A	Question and Answer
QA/QC	Quality Assurance and Quality Control
RWSE	Regional Wildlife Science Entity
SAP	Site Assessment Plan
SME	Subject Matter Expert
TRL	Technology Readiness Level
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VHF	Very High Frequency
WEA	Wind Energy Area

A glossary of terms is included as appendix F.

Summary

The New York State Energy Research and Development Authority (NYSERDA) convened a stakeholder workshop on March 4–6, 2020 with scientists and representatives of environmental non-governmental organizations (NGOs), regulators, and offshore wind developers. The workshop was designed to inform the development of a scientific research framework to guide the long-term study of potential effects to birds and bats from offshore wind energy development in the eastern United States. Workshop discussions focused on reviewing existing knowledge, identifying priority questions, developing hypotheses for different types of effects, and identifying data collection and analytical methods to test hypotheses. A small group of subject matter experts (SME) with taxonomic, methodological, and/or statistical scientific expertise (appendix B) will lead the continued development of the research framework following the meeting. The scientific research framework will identify key questions on the effects of offshore wind construction and operations on birds and bats, as well as identifying research hypotheses, study methods, and conceptual research projects to answer the key questions. The goal of the framework is to inform future research and monitoring efforts, including the direction of future research funding, and to help ensure that future studies are (1) focused on key priorities and (2) are designed appropriately to improve the state of knowledge.

S.1 Research Questions

Building on knowledge from European offshore wind energy development and from other industries, workshop participants developed research questions focused on understanding short- and long-term effects to birds and bats as well as improving our understanding of cumulative and population-level effects from offshore wind energy development. Specific research questions were identified around topics of collisions, displacement, attraction, and habitat change, including the following:

- To what levels are marine birds displaced from wind farms?
- What are the population-level impacts of displacement?
- Do changes in the underwater community around turbine foundations affect the distribution, abundance, or diet of marine birds?
- How comparable is bat activity offshore and onshore?
- How do offshore wind projects affect the presence, species composition, and activity of bats?
- What is the relationship between exposure and collision risk for various taxa?
- How accurate are collision risk model predictions for birds?

S.2 Research Methods

A variety of study methods were discussed during the workshop. For example, individual tracking technologies can be used to study avoidance and barrier effects, and aid in parameterizing collision risk models, including flight height information. Tracking also provides opportunities to study connectivity and sub-population dynamics, aiding in our understanding of potential population-level effects of development. Observational surveys from boats, planes, or other platforms are well-suited to examine avian distribution and abundance and displacement, as well as some types of behaviors. Acoustics can help answer questions about species composition for birds and bats at varying temporal scales. Imaging technologies can provide fine-scale information about behavior, including flight height, speed, and direction, and in some cases can also aid in identifying collisions. Radar technologies can provide data on animal movements at a range of spatial scales. LiDAR can be used to estimate flight heights. Physiological studies can be used to examine the individual and, by extension, the possible population-level impacts of sublethal behavioral effects. Diet information can be used to examine changes in prey availability (e.g., abundance, distribution, composition) as it relates to displacement from or attraction to offshore wind energy development activities, as well as to explore the potential energetic effects of changes in nutritional quality of forage and the trophic structure of communities.

Study methodologies must be carefully targeted to examine specific research questions. All study methods have limitations in their use, and study designs that do not properly account for these limitations (e.g., by ensuring that study methods are appropriate to the research question and based on current best practices, and that calibration or other testing is conducted prior to deployment where applicable) may fail to produce the desired data or improve our ecological understanding. Combining multiple methodologies with complementary strengths is a particularly important strategy to counter the limitations of individual methods and better address key questions.

S.3 Research Priorities

The workshop included a fruitful discussion on how best to design local- and regional-scale studies that have statistical power to adequately answer research questions, and on criteria for prioritizing research and choosing focal species for study. Workshop participants agreed that different types of research may need to be prioritized to inform different decisions, and suggested prioritizing studies that have the following characteristics or parameters:

- **Are feasible and practicable**, based on available methodologies and technology as well as the scope of the question.
- **Focus on priority species**, such as species of conservation concern, species for which little is known about potential impacts, and/or species most likely to be affected (based on local conditions, existing knowledge from Europe, or impacts from other industries such as land-based wind energy development).
- **Inform adaptive management**, meaning that results may inform decisions for future or existing projects via permitting decisions, operational implications, mitigation actions, or other means.
- **Address permitting risk**, including species and topics of stakeholder and conservation concern.
- **Focus on stressors** with the greatest likely effect or likelihood of causing a population-level decline (may be species-specific).
- **Leverage resources** to promote regional coordination and maximize logistical/cost efficiencies.
- **Balance needs at different scales**. To ensure the best outcomes for wildlife and the offshore wind industry, it was recognized that there is a need for research with a clear nexus for short-term action (e.g., permitting, mitigation) as well as a need for broad-scale, population-wide studies that inform our ability to understand the effects of offshore wind energy development more broadly and over the longer term. The latter is particularly important in the context of other stressors such as climate change.

S.4 Workshop Outcomes

Workshop participants recognized several immediate research and coordination needs, and made the following recommendations:

- **Data collection approaches for project-scale research and monitoring should be standardized** across development projects, so that data can be aggregated across projects to better understand potential cumulative impacts and inform adaptive management.
- **There is a need for robust baseline research** to improve our general understanding of populations and ecosystems, including existing levels of variability and potential changes relating to changing environmental conditions.
- **There is a need for carefully designed pre-construction monitoring plans** to inform our understanding of impacts as the industry progresses.

Workshop discussions converged around several research studies identified as potential first steps towards understanding the effects of offshore wind on birds and bats in the eastern United States, including the following:

- **A large-scale, collaborative collision and avoidance study** similar to the Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance Study (Skov et al. 2018), to continue technological development of collision detection systems, improve understanding of collision risk, and inform the development of future hypotheses on this topic in the U.S. offshore context.
- **Large-scale study(ies) of seabird displacement**, which could leverage project-specific digital aerial survey efforts in some cases. SMEs indicated that an effective before-after-gradient design, which could encompass likely levels of displacement as well as natural variations in abundance and distribution, would likely require monthly project-level digital aerial surveys for a minimum of two years, each pre- and post-construction, and would need to cover larger areas around project footprints than is currently recommended under the Bureau of Ocean Energy Management (BOEM) pre-construction avian survey guidelines.
- **A passive acoustic study of offshore bat presence and activity** involving deployment of acoustic detectors for multiple years on available offshore platforms, such as site assessment buoys, vessels, and offshore wind turbines, across a gradient of distances from shore and heights above sea level, to better understand the spatial and temporal patterns of bat activity in relation to environmental factors and the development phase (e.g., pre- versus post-construction).

Building off this workshop, SMEs will continue to hone research questions, hypotheses, and methodologies while developing a scientific research framework document to guide research on the effects of offshore wind development on birds and bats.

1 Developing a Research Framework for Birds and Bats

Wind energy is an essential component of strategies to minimize climate change, but wind energy development also has direct and indirect effects on birds and bats. In the marine environment, many water birds have the potential to interact with offshore wind energy development during all parts of their life cycle. Terrestrial species, including songbirds, shorebirds, and bats, may also use the offshore environment, particularly during migratory periods, and thus have the potential to interact with offshore wind infrastructure. In order to develop offshore wind on the Atlantic coast of the United States in an environmentally responsible way, it is important to continue improving our understanding of these effects to inform adaptive management of future projects as the industry develops in the U.S.

The Massachusetts Clean Energy Center (MassCEC) and BOEM recently funded an effort to develop a scientific research framework for understanding the effects of offshore wind energy development on marine mammals and sea turtles along the Massachusetts and Rhode Island coastline (Kraus et al. 2019). The Environmental Research Program at New York State Energy Research and Development Authority (NYSERDA) recognized the utility of this framework for guiding future funding and research, and committed to supporting the development of a research framework for birds and bats under the auspices of the Environmental Technical Working Group for Offshore Wind[1] (E-TWG) and with technical and facilitation support from the Biodiversity Research Institute (BRI) and the Consensus Building Institute (CBI), respectively.

The scientific research framework will build off existing work to understand the effects of offshore wind energy development on birds and bats, including displacement from, and attraction to, offshore wind facilities (Vanermen et al. 2015a, Dierschke et al. 2016, Mendel et al. 2019); barrier effects (Masden et al. 2009, 2010); collision risk (Masden and Cook 2016, Allison et al. 2019); and assessments of artificial reef effects and construction impacts to foraging habitat and forage fish populations (Perrow et al. 2011a, Slavik et al. 2019). The goal of this framework is to inform future research and monitoring efforts, including the direction of funding from both governmental and private entities by accomplishing the following:

- Identify key questions on the effects of offshore wind construction and operations on birds and bats.
- Develop research hypotheses, study methods, and conceptual research projects to answer key questions.
- Identify data gaps and technological deficiencies that may inhibit our ability to answer these questions.

The research framework may include consideration of potential short-term, long-term, and population-level effects to birds and bats from offshore wind energy development, including changes to distributions, abundance, behavior, or demography. The geographic scope of the framework effort aligns with the E-TWG, with a regional scope from Massachusetts to North Carolina and a focus on offshore wind energy development in federal waters. NYSERDA convened this three-day stakeholder workshop as the first major step toward the development of the scientific research framework.

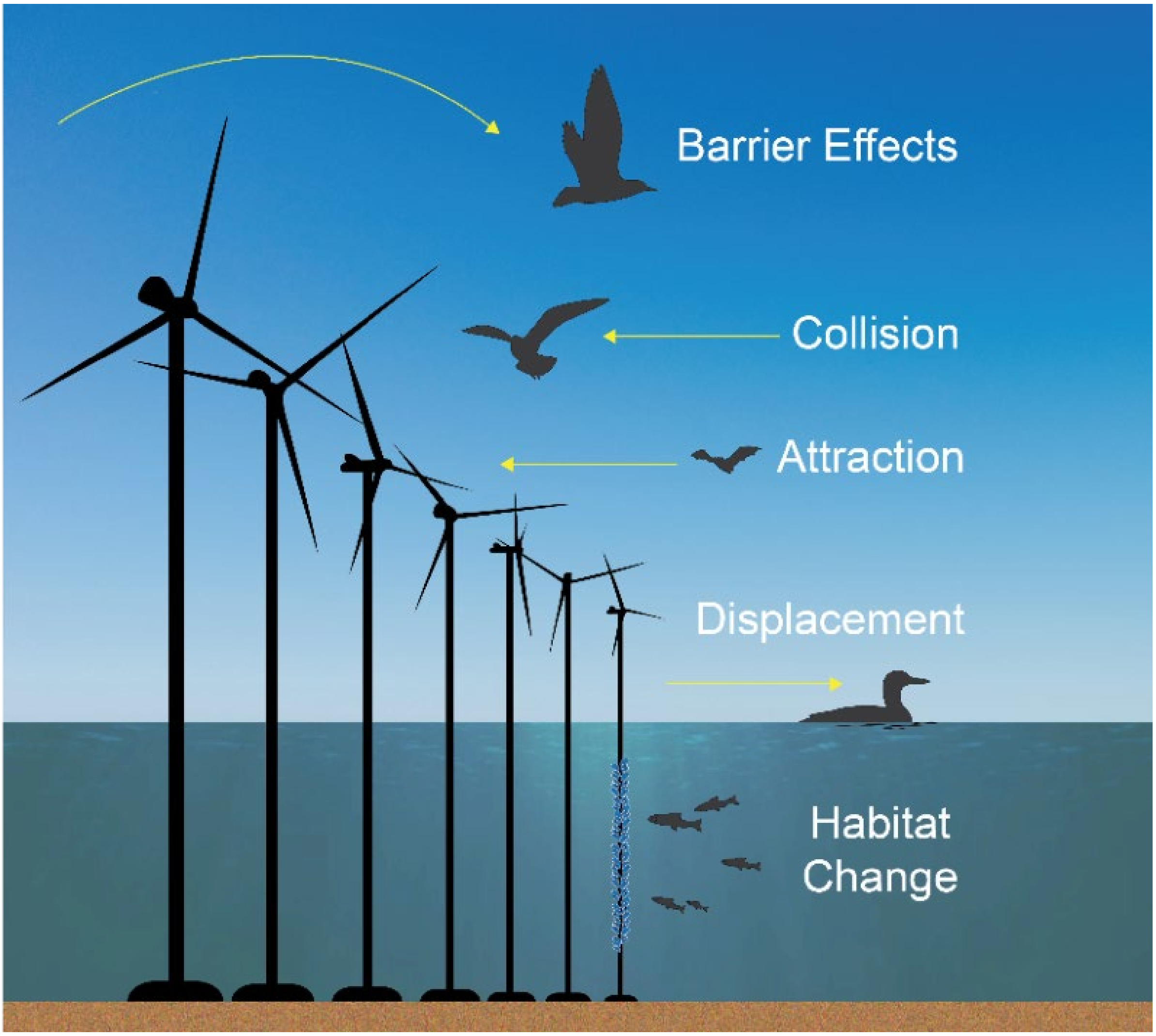
1.1 Workshop Purpose and Scope

The workshop opened with Kate McClellan Press (NYSERDA) and Kate Williams (BRI) reviewing the purpose and scope[2] of the workshop. Workshop discussions were framed around reviewing existing knowledge about impacts to birds and bats from displacement, barrier effects, collision risk, and habitat change (Figure 1); identifying priority questions; developing hypotheses for different types of effects; and identifying data collection and analytical methods to test hypotheses (meeting agenda is included in appendix A). The speakers noted some key lessons learned from offshore wind energy development to date; for example, while collision is difficult to detect in the offshore environment, it is likely less common than in terrestrial systems (Cook et al. 2018a, Skov et al. 2018). Displacement, however, is fairly common for many species of marine birds, although the type and degree of response can vary greatly (Dierschke et al. 2016). A significant amount of knowledge on effects to birds and bats comes from project-specific and strategic monitoring at European wind farms, but that monitoring has not always been able to answer the questions being posed. Studies must be carefully designed to deal with the highly variable marine environment and ensure sufficient power to differentiate the effects of offshore wind energy development from other sources of variation. The goal for the workshop was to identify top priority research questions and methods for answering those questions, to begin developing the scientific research framework for the eastern U.S. and to avoid a DRIP (data rich and information poor; Wilding et al. 2017) situation as the offshore wind industry develops in the U.S.

Figure 1. Major Types of Potential Impacts to Wildlife from Offshore Wind Energy Development

Displacement is when animals adjust their habitat use, such as foraging or breeding, due to a new feature or disturbance, causing effective habitat loss. Barrier effects occur when animals detour around an area during directional movements, such as migration or foraging flights, potentially resulting in increased distance traveled and energetic costs. Attraction is when animals adjust their habitat use towards a new feature. Animals may collide with turbines or other structures as a result of attraction and/or a lack of avoidance behavior. Habitat change, including artificial reef effects and other changes to prey populations and habitats, may mediate behavioral, physiological, or energetic changes to predator populations.

Source: BRI.



The workshop was designed to be highly participatory, building on information from technical presentations through a series of full group and breakout group discussions. The full complement of 48 workshop attendees, present in person or via webinar/conference call on 4–5 March, 2020, included a broad range of stakeholders with technical expertise, including scientists, environmental NGOs, regulators, and offshore wind developers (appendix B). Following the first two days, a smaller group of subject matter experts (SME) on bird and bat taxa participated in a technical working session on 6 March, 2020 (appendix B). They refined hypotheses and study methods developed during the first two days of the workshop to begin generating key elements of the research framework. The research framework document will be drafted in large part based on the three days of stakeholder input, with opportunities for additional review and input by SMEs.

Presentations that reviewed existing knowledge and informed discussions are summarized below, followed by summaries of group discussions. In sections 4–6 of this report, an effort was made to preserve the content of plenary sessions as presented by speakers. Topics included in these presentations may also have been discussed in further depth or with differing perspectives in subsequent workshop discussions (sections 7–9). All presentations are available on the workshop website.[3]

2 Regulatory and Development Context

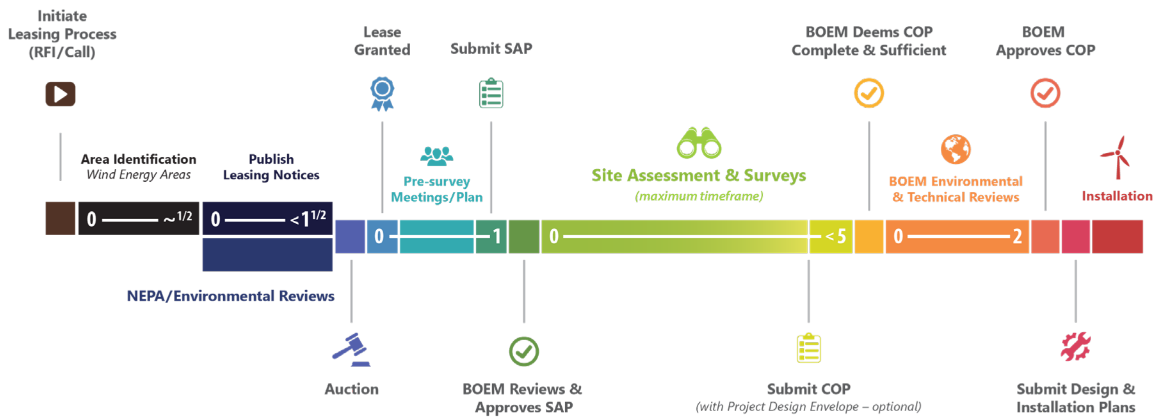
2.1 Regulatory Context

David Bigger (BOEM) presented an overview of the regulatory context for developing a research framework.[4] BOEM's mission is to manage ocean energy and mineral resources on the Outer Continental Shelf (OCS) in a safe and environmentally sound way. The renewable energy authorization process includes four distinct phases (planning, leasing, site assessment, and construction and operations), and three main environmental review points (Figure 2). To date, BOEM has held eight offshore wind lease sales resulting in 15 commercial leases for over 1.7 million acres of the OCS. Bigger noted that BOEM is in the process of identifying additional potential wind energy call areas in several regions of the OCS. This involves deconflicting potential call areas prior to identifying wind energy areas, using a variety of data including wildlife considerations as well as navigation, fisheries, and Department of Defense uses. BOEM's Environmental Studies Program (ESP) funds scientific research to inform policy decisions throughout the regulatory and permitting process, such as studies to identify vulnerable populations, understand abundance and distribution patterns, and understand wildlife movements. The ESP also aims to make this data as accessible as possible, including on data portals such as the Northeast and Mid-Atlantic Ocean Data Portals.[5]

Figure 2. BOEM Offshore Wind Development Timeline

Includes four distinct phases: planning, leasing, site assessment, and construction and operations. There are three main environmental review points in this process: National Environmental Policy Act (NEPA) and other environmental review prior to a lease auction; the review of the Site Assessment Plan (SAP); and the review of the Construction and Operations Plan (COP), which involves drafting an environmental impact statement (EIS).

Source: BOEM.



2.2 Development Context

Representatives from two offshore wind leaseholders presented brief overviews of their projects and engagement on bird and bat research.

- Brita Woeck (Ørsted) provided perspectives on the ongoing research at the first operational U.S. offshore wind energy facility, the five-turbine Block Island Wind Farm located off the coast of Rhode Island. This post-construction work includes testing of a turbine-mounted radar system paired with thermal cameras, focused on collecting information on wildlife movements and potential collisions at two turbines. In addition, there is a radio telemetry receiving unit that is integrated into the Motus Wildlife Tracking System[6] to help examine the movement of radio-tagged wildlife along the eastern seaboard. Woeck noted the importance to offshore wind energy developers of focusing research priorities on areas of highest risk and uncertainty, leveraging existing data and studies, and building off existing knowledge from wind farms in Europe and around the world.
- Louis Brzuzy (Shell New Energies) noted high-resolution marine bird surveys conducted for Shell's Atlantic Shores and Mayflower offshore wind projects to inform construction and operations planning, and suggested looking to examples from joint industry programs in the United Kingdom (UK) and the Netherlands that are bringing together stakeholders to fill gaps in knowledge around wildlife effects. He also reiterated the importance of reducing uncertainty in the data to make more informed decisions, particularly around siting.

3 Overview of Current Knowledge

The plenary session focused on reviewing the state of the science on effects from offshore wind energy development on birds and bats. This included reviews of collision and displacement studies from Europe, and existing data and studies from the eastern U.S. that could inform our understanding of species' distribution, abundance, and movement patterns. Topics of discussion from Question and Answer (Q&A) periods are summarized in appendix C.

3.1 European Review: Seabird Displacement and Barrier Effects

Ib Krag Petersen (Aarhus University, Denmark) presented an overview of current knowledge on displacement and barrier effects for seabirds from European offshore wind farms.[7] Offshore wind energy is being developed in most European countries with marine territorial waters. The UK and Germany have the largest offshore wind industries, followed by Denmark, Belgium, and Holland. As the industry has developed, survey methods have also evolved. Petersen indicated that survey methods using total counts are now seldom used in Europe in favor of line transects with a distance sampling design, as this method allows for the derivation of density estimates and development of models to predict densities across unsampled areas. Ship-based and aerial surveys with human observers have been replaced in many countries with digital aerial surveys (video and still imagery), which allow planes to fly higher and, because they provide more precise measures of survey areas, can also lead to improved predictions of species distributions and abundance.

European studies have found that some seabird species that winter in European waters, particularly red-throated loon, common scoter, and long-tailed duck, show avoidance of offshore wind farms. The red-throated loon has been widely studied across Europe with similar results of displacement up to 15 kilometers (km) from wind farms, including studies in Germany (Dorsch et al. 2019, Mendel et al. 2019) and Denmark (Petersen et al. 2006, 2014). Similarly, common scoters and long-tailed ducks exhibited displacement out to about 5 km at a wind farm in Denmark. In some instances, there is no evidence of habituation even 15 years after wind farm construction. Other species of seabirds show differing responses to the presence of wind farms. A study in Denmark found that cormorant species showed high levels of attraction, using the structures for perching sites, while northern fulmars and northern gannets exhibited avoidance (Leopold et al. 2011). Lesser black-backed and great black-backed gulls have exhibited either no change in behavior or higher densities within the wind farm (Leopold et al. 2011, Welcker and Nehls 2016).[8] Petersen indicated that the current regulatory approach in the European Union (EU) is that if a proposed wind farm does not cause population-level impacts, then it is acceptable to build; however, he noted that it has become clear that understanding cumulative impacts is also critical.. The population-level impacts of displacement are particularly challenging to assess. Population dynamics and agent-based models could be helpful tools to examine the question of population-level impacts from displacement.

3.2 European Review: Seabirds and Collision Risk

Aonghais Cook (British Trust for Ornithology) reviewed the state of knowledge regarding collision risk to seabirds from the European offshore wind industry.[9] Because of the high profile of collision fatality incidents from some terrestrial wind farms, he indicated that collision is often seen as a highly important potential effect. In Belgium, for example, a coastal (onshore) wind farm located near a Sandwich tern breeding colony recorded up to 50 collisions annually (Everaert et al. 2007). Cook indicated that this demonstrates the importance of siting to reduce collision risk. In the UK, concerns over the potential impact of collisions on seabird populations have resulted in some projects not receiving planning consent (Broadbent and Nixon 2019), and have led to legal challenges by environmental organizations. However, there are very few records of collisions offshore (Pettersson 2005, Desholm 2006, Newton and Little 2009, Skov et al. 2018); collisions do occur, but they are quite difficult to detect. In the absence of robust data, precautionary values are often used in EU countries for assessments related to collision risk. Cook noted that some developers have expressed concern that the use of precautionary estimates across projects has led to overestimates of population-wide impacts rather than representing reasonable worst-case scenarios for cumulative effects. For example, Busch and Garthe (2018) estimated a cumulative impact across all offshore wind farms in the North Sea of 352 collisions annually for a single black-legged kittiwake breeding population, while another study estimated a ~9% increase in annual mortality of great and lesser black-backed gulls (Brabant et al. 2015).

In Europe, collision risk is predicted using collision risk models (CRM). While there are a variety of models available, most use the Band model (Band 2012), which was first developed for use onshore and has since been expanded for offshore use and improved to better represent uncertainty. Model parameters include turbine variables and species-specific variables related to local densities, morphometrics, and flight behavior, and provides an estimate of annual numbers of collisions by species. There is substantial uncertainty around many of these parameters, and the model is particularly sensitive to uncertainty in avoidance rates. Avoidance is calculated as 1 - (observed collision rate/predicted collision rate), and often relies on literature review to estimate avoidance rates for key species of collision risk concern, including northern gannets, lesser black-backed gulls, herring gulls, great black-backed gulls, and black-legged kittiwakes. As additional technologies are developed, such as GPS tags and turbine-mounted camera and radar systems, it is becoming more feasible to study avoidance behavior around turbines, but the challenge remains in our inability to measure avoidance *rates*, or more specifically the "non-avoidance" rate used in CRMs, as avoidance happens at a variety of spatial and temporal scales. Variables besides avoidance rate also drive estimation of risk in CRMs, including flight speed and flight height. Other factors that may influence birds' behaviors and thus change values used in CRMs, such as time of day and weather conditions, are not currently included in models. There have been a few studies of raptors in Spain that have attempted to validate the Band model by comparing predicted collision risk versus true risk, and they found that there was low correlation between these two measures (e.g., De Lucas et al. 2008). However, in the absence of robust alternatives, Cook indicated that CRMs remain an important tool. Stochastic models are being built to better reflect uncertainty (McGregor et al. 2018) and understand how risk varies spatially and temporally, while also incorporating new information from technology such as GPS telemetry to help improve our understanding of collision risk.

3.3 Seabird Distribution and Abundance Data and Models for the Eastern Unites States

Arliss Winship (CSS Inc., contractor to the National Oceanic and Atmospheric Administration—National Centers for Coastal Ocean Science; NOAA NCCOS) provided an overview of existing seabird distribution and abundance data for the eastern U.S.[10] One of the main repositories of boat-based and aerial survey data is the Northwest Atlantic Seabird Catalog (formerly the Avian Compendium; hereafter 'Catalog'), which was developed at the U.S. Geological Survey (USGS), managed for a period by the U.S. Fish and Wildlife Service (USFWS), and now is being managed by NOAA. The data originates from various sources (government agencies, non-profits, academics, other groups) and as such, the spatial and temporal extent of individual data sets is highly variable, as are the platform (ship, visual aerial, digital aerial), methodology (strip transects, distance sampling), and availability of auxiliary information (sighting conditions, behavior).

In recent years, NOAA NCCOS used these at-sea survey data in spatial modeling efforts to predict relative abundance of different seabird species by season across a large spatial extent, using environmental covariates as predictors (Winship et al. 2018). The outputs, available through the Northeast Ocean Data Portal, included maps for 140 different species-season combinations, representing predicted distributions of relative density, with companion maps reflecting the bootstrapped estimated uncertainty of the predictions. This effort also estimated the proportion of each species distribution within BOEM wind energy areas. Maps represent relative density, rather than true density or probability of seeing a given bird in a given location and represent a long-term average from the 1970s to the 2000s rather than the distribution in a particular year.

There have been several regional baseline studies to describe animals' offshore patterns of distribution and abundance, including in the mid-Atlantic U.S.,[11] Massachusetts and Rhode Island,[12] the New York Bight,[13] and ongoing surveys in the South Atlantic Bight,[14] as well as project-specific surveys by developers. There is also a coastwide survey effort, the Atlantic Marine Program for Protected Species (AMAPPS) surveys, which are conducted by BOEM and USFWS.[15] All relevant data not already in the Catalog will hopefully be submitted to the database to include in future modeling efforts. BOEM has recently funded NOAA NCCOS to perform spatiotemporal modeling that aims to build upon earlier efforts, allow for changes in distributions over time, and forecast distributions into the future under different climate scenarios.

3.4 Seabird Movements and Finer-Scale Habitat Associations in the Northwest Atlantic

Pam Loring (USFWS) provided an overview of the three main technologies used to track the movement of birds offshore (automated radio telemetry, satellite tracking, and GPS tracking),[16] with examples from the U.S. east coast.

Automated radio telemetry uses radio transmitters with a digital code that uniquely identifies tagged individuals on a shared frequency. Nanotags, the most common of this type of transmitter to date, range from 0.2–3.0 g, so are suitable for many smaller-bodied species.[17] These transmitters are detected via a network of receiving stations with a typical detection range of ~20 km (although this varies with receiver configuration and tag altitude) and a temporal resolution of 2–10 seconds. Birds Canada has supported the development of the Motus Network, a collaborative network of receiving towers with over 800 receiver stations in North and South America and over 200 million detections to date. This technology can be deployed on small-bodied animals and can provide regional-scale information, but requires locations to deploy receiver stations, and when birds leave that detection range, it is no longer possible to track their movements. Examples of studies using this technology include the following:

- A BOEM-funded digital Very High Frequency (VHF) telemetry project (2014–2017) focused on tracking the movement of common terns, roseate terns, and piping plovers in relation to offshore wind energy areas (Loring et al. 2019).
- Pilot studies with receiving stations on a turbine at the Block Island Wind Farm (in collaboration with Ørsted) and a buoy in the New York Bight (in collaboration with NYSERDA).
- A new project with USFWS, NYSERDA, BRI, Birds Canada, and the University of Rhode Island focused on developing monitoring protocols for automated radio telemetry studies at offshore wind farms.

Satellite tracking uses the ARGOS system[18] and estimates transmitter location based on Doppler shift; data are transmitted over the internet. Tag weight ranges between 2.5–100 g, and temporal resolution and battery life vary with size. Spatial resolution is 250–1500 m. In 2017, USFWS and BOEM were involved in a satellite telemetry study using 2g solar tags on common terns (n=5) during the breeding season in Maine to provide fall migration data on travel across offshore wind lease areas.

GPS tracking technology has greater spatial accuracy than satellite tracking (<10 m). Data acquisition depends on the model. The lightest tags are archival (1 g minimum), while some transmit via VHF base station when in range (2 g min), and heavier tags transmit data via ARGOS or GSM (49 g min). Auxiliary information, such as altitude, can also be recorded in addition to location data. The temporal resolution varies and is customizable but relates to size and battery capacity. Examples of projects using GPS include the following:

- GPS tags deployed on common and Arctic terns in the Gulf of Maine (2019) that relayed (via VHF to base stations) an average of 28 points per day for up to 75 days, although there was a high level of nest abandonment (~50%).
- A study on northern gannets using GPS-GSM tags tracked individuals in the mid-Atlantic, Virginia, and Newfoundland (2015-2016; Spiegel et al. 2017).

Loring indicated that all three tracking methods can provide important information on the movement and behavior of individuals. Digital VHF is often the most suitable option for studying offshore movements of species with a body weight of <50 g, given tag size and data download limitations of the other technologies.[19] Satellite telemetry is good for estimating space-use across broad geographic areas, while GPS is best for high-resolution tracking and altitude data. There are limitations to using raw tracking data for risk assessments due to differences in sampling design, study time frame, spatial and temporal resolution, and detection probability, so study products (i.e., published reports, modeled data layers) may have greater utility. These derived products can be found on the Northeast and Mid-Atlantic Ocean Data Portals and in reports from the BOEM Environmental Studies Program,[20] Tethys Knowledge Base,[21] and the Motus Network.[22]

3.5 Migration of Terrestrial Birds in the Offshore Environment

Andrew Farnsworth (Cornell Lab of Ornithology) reviewed existing knowledge of terrestrial birds in the offshore environment.[23] While a great deal of anecdotal information about the migration of terrestrial songbirds offshore exists, the quantitative data is limited. Over the last 50 years, and through the more recent use of geolocator technology, understanding of songbird migration at large spatial scales has improved; for example, it is now known that many species, such as the blackpoll warbler, depart from the eastern seaboard and fly over the Atlantic during fall migration, and thus have the potential to interact with offshore structures and human activities. Studies of the oil and gas industry in the Gulf of Mexico have used acoustic monitoring on offshore oil platforms (Russell 2005) and found that these platforms have three primary proximate effects on migrating birds: (1) provide habitat for resting and, in some cases, refueling (e.g., raptors), (2) inducing nocturnal "circulations," in which birds become attracted and disoriented and may circle the platforms until they become exhausted or collide with structures, and (3) resulting in some mortality through collisions. Nocturnal circulation events tended to occur under certain weather and lighting conditions, and were highly variable in size and species composition, although herons, shorebirds, swallows, and warblers were dominant components.

In the northwest Atlantic, information from the oil and gas industry is only available at higher latitudes, but there are other sources of data such as eBird.[24] An effort by eBird to map relative abundance through time, while terrestrial in nature, provides information about potential jumping off locations and species that may depart from northeastern North America over the Atlantic. While not designed to collect data on terrestrial migrants, boat surveys have also documented these species, providing additional information on species occurrence offshore, as well as potential behaviors and inter- and intra-specific interactions. Another source of information is BirdCast,[25] which forecasts bird migration in real-time using weather surveillance radar data. There are 143 weather surveillance radars in the U.S. that are excellent at observing the atmosphere and detecting both meteorological and biological phenomena. While these systems are located on land, coastal units can provide some information on offshore movements (particularly at higher altitudes) and potential jumping-off locations for birds departing over the ocean. These different sources of data can be combined to begin to understand the magnitude and spatiotemporal patterns of terrestrial migrant use of the offshore environment.

3.6 Bats and Offshore Wind

Trevor Peterson (Stantec) provided an overview of what is known about bat movements in the offshore environment.[26] From the terrestrial wind industry, it is clear that bats are susceptible to turbine impacts, and that migratory bat species represent about 75% of bat fatalities at terrestrial wind projects. Fatalities are highly seasonal, with highest risk during fall migration, and to some degree during spring migration, but risk varies tremendously with environmental conditions. Risk is contingent upon turbine operation; non-spinning turbines pose little or no risk for bats (although this may not be the case for birds).

Bats are detected everywhere that has been examined via acoustic studies and anecdotal reports offshore, but they are not detected consistently. Because information offshore is primarily based on data collected from acoustic detectors on ships, buoys, and lighthouses, data are lacking on the absolute number of bats offshore, but there is some information on patterns in relative activity levels. From studies in the Gulf of Maine and the Mid-Atlantic, seasonal distribution of bat activity offshore appears similar to onshore (Stantec Consulting Services Inc. 2016). A recent study on the U.S. east coast that deployed acoustic recorders on buoys 6–26 km from the mainland found that eastern red bats represented more than two-thirds of detections, with a pronounced seasonal activity peak during summer and fall (Stantec Consulting Services Inc. 2016). Data from buoys as well as other platforms (ranging from 4–42 km from the mainland) also showed higher acoustic activity levels during calm, warm conditions (Stantec Consulting Services Inc. 2016). In Europe, the few acoustic studies of bats offshore have shown the same seasonal migration patterns, with activity levels driven by wind speed, temperature, and moon phase (Lagerveld et al. 2017).

Peterson indicated that bat occurrence offshore is not yet well enough understood to minimize risk from offshore wind energy development through siting, but that it is clear there will be high-seasonal variation in risk, and that the magnitude of this risk is difficult to estimate. It has been recommended at a few offshore wind farms in Europe that curtailment be implemented during fall migration to minimize bat mortalities. As most bat activity occurs during low-wind speeds, potential minimization strategies related to turbine operation could potentially have a large effect on impact reduction without a great deal of power loss, but it is currently unclear whether such approaches are warranted for the U.S. Atlantic coast.

4 Overview of Study Methods

This plenary session focused on reviewing the available study methods for examining potential effects to birds and bats from offshore wind energy development, highlighting limitations in available methods, and emphasizing the importance of careful study design to ensure that research studies can answer key questions. Topics of discussion from Q&A periods are summarized in appendix D.

4.1 Overview of Data Collection Methods: Displacement, Barrier Effects, Habitat Effects

Andy Webb (HiDef Aerial Surveying) provided an overview of data collection methodologies for studying displacement and barrier effects for marine birds.[27] Extensive monitoring is conducted post-consent (i.e., following approval of environmental impact assessments) at European offshore wind farms to help improve estimates of effects on marine birds and inform the next round of development. Most resources are directed at the effects that have been determined most likely to be significant, leading to greater emphasis on displacement in marine birds than on habitat change or barrier effects for long-distance migrants. In general, studies use a hypothesis-testing approach. Early displacement studies were designed using the Before-After-Control-Impact (BACI) methodology with boat-based surveys. While some studies showed evidence of displacement effects (e.g., Vanermen et al. 2015), this methodology tended to have poor statistical power to detect change as well as challenges relating to non-representative control sites. These issues led to many inconclusive studies and a shift to Before-After-Gradient (BAG) studies, which use spatially explicit modeling to look for significant changes in distributions within wind farm footprints as compared to surrounding areas. BAG designs handle high levels of spatial variation in bird densities by focusing on the relative change in densities over time within and at varying distances from the wind farm. In addition, Webb indicated that there has been a shift from visual to digital aerial surveys for before-after comparison studies in Europe, in large part because digital approaches allow post-construction surveys to be flown above turbines rather than at the altitude of the rotor-sweep zone. Spatially explicit modeling to examine displacement is relatively insensitive to some specifics of survey design (e.g., platform, transect location, and orientation), allowing for some flexibility in data collection method, but it is important to sample the same spatial extent over time, and to survey a large enough area to encompass both the wind farm and locations to which the birds are displaced. Power analysis is a key aspect of study design to inform decisions such as the number of surveys to be conducted. There are also other methods that can be used to study displacement, including Bayesian Point Pattern Analysis[28] and simulation approaches to compare measured distributions with those expected to occur by chance (Trinder 2016, Leopold 2018, Vilela et al. 2019).

There are also methods to study displacement at the individual level using tracking data. Examples include a satellite tagging study of wintering red-throated loons (Dorsch et al. 2019), and a GPS tagging study of breeding adult lesser black-backed gulls (Thaxter et al. 2018). To better understand the potential effects of displacement on energetics, the simulation model SeaBORD (Searle et al. 2018) predicts daily individual time-energy budgets using a number of inputs including prey parameters, percent displacement rate, and individual colony data. The key output is a prediction of adult and chick survival as a measure of population-scale impact.

Barrier effects relate to the energetic demand of changing a movement pathway to avoid a wind farm. These can be barriers for feeding movements, such as the movements of central place foragers, or barriers for long-distance migrants. There are a few studies looking at barrier effects that have used radar, including a study of pink-footed geese that found avoidance behavior once wind farms were built (Plonczkier and Simms 2012).[29] The main challenge with this technology is that you cannot get good species identification, so radar data for this purpose needs to be supplemented with auditory and/or visual data.

There is a poor understanding of effects due to habitat modification, even at the qualitative level. This relates to logistical difficulties associated with sampling and monitoring fish populations, as well as the scale at which effects are likely occurring (i.e., from individual turbines to the entire wind farm). Changes to habitat and prey resources may occur through modification of human pressures (i.e., reduction of fisheries activities) and artificial reef effects. Reef effects increase localized primary productivity as well as the local density, biodiversity, and biomass of benthic organisms and fishes (Methratta and Dardick 2019, Slavik et al. 2019, Dannheim et al. 2020). However, it remains unclear whether increases in biomass of upper-trophic level organisms are due to increased recruitment (e.g., increased carrying capacity), or simply to a concentration of biomass from the surrounding area in response to food abundance or availability at wind farm sites (Wilhelmsson and Malm 2008, Inger et al. 2009).

4.2 Existing, New, and Emerging Technologies for Measuring Collisions

Jocelyn Brown-Saracino (U.S. Department of Energy (DOE) Wind and Water Power Technologies Office) provided an overview of technological approaches for monitoring bird and bat collisions at offshore wind farms.[30] Collision risk incorporates both exposure and avoidance, and just because a bird is in the area of a wind farm does not mean it will collide, as avoidance occurs on multiple scales (e.g., macro-, meso-, micro-avoidance). While there have been several decades of land-based collision monitoring, many of the methodologies are not transferable offshore. Collision impacts in the offshore environment can be examined in two ways: (1) by measuring avoidance, and in turn, using this information in collision risk modeling to estimate population-level impacts and (2) by developing tools to measure collisions directly. Collision risk modeling is a widely used tool in Europe, but these models are highly sensitive to avoidance rates. Some of the best information on avoidance comes from large-scale studies in Europe. For example, the ORJIP Bird Collision Avoidance Study (Skov et al. 2018) used multiple methodologies including observers with range finders, radar, and a thermal detection tracking system to study avoidance at a wind farm, and concluded that birds exhibited high levels of avoidance behavior. Evaluating technologies that directly measure collision requires an understanding of the percentage of collisions that were not detected (i.e., false negatives) as well as detections that were not actually collisions (i.e., false positives). In addition, it would be beneficial when monitoring for collisions to measure the percent of birds that fly through the rotor-swept zone without having to take avoidance action (e.g., that fly between the blades) as well as those that initiate avoidance behaviors to avoid collision.

There are a number of collision monitoring technologies in development, mostly in a terrestrial context (in part because the logistics of testing and validation are simpler than offshore). Most systems include components to detect collision events and to classify the animals involved in collisions to some level of taxonomic specificity. Systems vary in spatial coverage and ability to operate in different conditions (i.e., time of day, weather). No collision detection systems are currently at a Technology Readiness Level (TRL) of 9, which indicates full validation and readiness for commercial deployment offshore. A comprehensive review of existing technologies is available (Dirksen 2017) and Brown-Saracino noted the following examples:

- **DT Bird**—uses accelerometers, contact microphones, and a camera. Extensively tested onshore; efforts are in the works to begin offshore testing and increase system sensitivity to better detect smaller targets. TRL: Mid-High
- **Thermal Animal Detection System (TADS) & Multi-Sensor Bird Detection System (MUSE; DHI)**—combines thermal cameras and radar, with the radar scanning a larger area than the camera can cover. When detected on radar, the camera tracks the object through space. The technology is currently being validated at the Block Island Wind Farm and is experiencing high rates of false positives. TRL: High
- **Visual Automatic Recording System (VARS; IfAÖ)**—uses motion-controlled infrared cameras; has a relatively narrow field of view and records successful passage through the rotor swept zone rather than direct collisions. Technology has been deployed offshore. TRL: High
- **Avian and Bat Collision Monitoring System (Oregon State University)**—uses integrated accelerometers, gyrometers, and contact microphones coupled with a 360-degree camera system. This system has only been tested in a controlled environment. Ongoing work is focused on increasing sensitivity to small objects. TRL: Mid
- **Aerofauna Collision Avoidance Monitoring System (HiDef, BRI)**—uses visual and thermal cameras to track and automatically classify objects around wind turbines. This proof-of-concept system has only been tested onshore. TRL: Mid
- **ThermalTracker Software (PNNL)**—software in development for thermal camera systems to automate bird flight tracking, behavior analysis, and object identification. Currently this system is being validated onshore using drones, with plans for offshore testing. TRL: Mid

There are challenges with measuring collision risk offshore, including (1) the necessary scale of coverage, both of the rotor-sweep zone and across a wind farm, (2) the state of technology readiness relative to the questions that drive regulation (i.e., challenges in identifying individual species), (3) handling large amounts of data, (4) operations and maintenance in the harsh marine environment, and (5) methods and sample sizes needed for validation of technologies and comparison with collision estimates. Collisions are rare events, making detection of these events statistically difficult to extrapolate to necessary scales. In addition, many existing systems provide count data for collisions, but do not provide information on the number of birds flying through the wind farm and not colliding (either through avoidance or by chance), limiting the utility of this information for predicting risk. Current collision detection systems offer promise for long-term monitoring, but additional technology research and development is needed prior to commercial deployment.

4.3 Analytical and Statistical Approaches for Testing Hypotheses

Andrew Farnsworth (Cornell Lab of Ornithology) discussed analytical and statistical approaches for testing hypotheses, in preparation for workshop participants to begin developing research questions regarding impacts to birds and bats from offshore wind energy development. The goal of hypothesis testing is to test a statement regarding unknown population parameter values based on sample data. In a frequentist framework, for example, a null hypothesis is developed—that is, a statement that implies no association between the explanatory and response variables (e.g., there is no difference in the distribution of red-throated loons before and after wind farm construction)—along with an alternative hypothesis, or statement contradictory to the null hypothesis. Studies should be designed to be able to adequately test hypotheses. As a general rule, statistical power (the probability of coming to an accurate conclusion about the tested hypothesis) increases as sample size increases, as population variance decreases, and as the true mean difference (e.g., effect size) increases. Several challenges can influence our ability to answer questions about the potential effects to birds and bats from offshore wind development, including the following:

- **Small sample sizes.** Collisions and detections of listed species are rare, leading to zero-inflation (see below) and substantial uncertainty in estimates, especially when attempting to scale observed effects from a small sample to an entire wind farm or population.
- **Zero-inflation.** Observations, whether from collision monitoring or at-sea surveys, are often rare, leading to a large number of zeros in data sets. These may be true zeros or may be a function of sampling scheme and thus may not represent true absence. Zero-inflation can greatly complicate statistical analysis, although approaches do exist to help address the issue (see Zipkin et al. 2015 for an offshore wind-related example).
- **Spatiotemporal variability.** There is often substantial variability in distributions of marine birds offshore, so studies need to be designed to ensure the statistical power to detect a given effect size. This requires sampling regimes that adequately capture variation in the distribution of organisms due to local environmental variability as well as larger-scale climatological oscillations. Spatiotemporal variability is also an important consideration for studies of terrestrial migrants, including songbirds and bats; offshore movements may be sporadic and strongly influenced by environmental factors. In designing studies of displacement, habitat change, and prey impacts, the effectiveness of BACI versus BAG designs should also be considered.
- **Understanding the biological significance of effects.** The first research step is detecting an effect. Once detected, the second step is understanding what that effect means for the survival or reproduction of individuals, and then for population status and demography, which can require a great deal of additional information.

5 Group Discussions on Presented Materials

Following the above presentations and Q&A periods (appendices C–D), workshop attendees identified several areas that required additional clarification from other workshop participants, including state and federal agency representatives:

- **What are pre-construction monitoring and Construction and Operations Plan (COP) requirements for birds and bats?** Pre-construction monitoring is not required by BOEM, but their pre-construction avian survey guidelines encourage the use of surveys, particularly when there are limited preexisting data for an area (BOEM 2020). The guidelines include recommendations for how survey information should be collected, including the recommendation that surveys be conducted monthly for two annual cycles to capture peak abundance and inter-annual variation. AMAPPS surveys are coarse in spatial and temporal resolution, which makes it difficult to rely on them in place of site-specific information. Thus, many developers are conducting some kind of pre-construction surveys. While these are somewhat standardized due to a limited number of service providers, the scope and design of surveys varies considerably between projects. The data are transferred to BOEM quarterly and then used to put together the final COP. The COP presents information on what species have the potential to occur within the area of the project and how those species may be affected.
- **How does data standardization and data sharing work for offshore wind projects?** BOEM recommends that all survey data from developers be submitted to BOEM and made public. Offshore survey data are stored in the Northwest Atlantic Seabird Catalog and are publicly available with some restrictions for individual data sets. Following the BOEM survey guidelines helps to ensure data standardization across projects. BOEM also funded the development of an application called SeaScribe[31] that can be used to collect survey data in a standardized way and easily submit the data to NOAA for inclusion in the Catalog. Bat acoustic data, including offshore data, can be submitted to BatAmp.[32]
- **What are the Endangered Species Act (ESA) requirements for offshore wind projects?** If there is anticipated "take" of endangered species from an offshore wind energy development, BOEM is required to obtain an incidental take statement through consultation with USFWS. Any requirements laid out by USFWS to minimize impacts to listed species are then incorporated into the developer's permits for the project. However, there is currently substantial uncertainty in how this process will be applied in the case of potential impacts from offshore wind energy development across the U.S.

Workshop participants also reflected on key takeaways, challenges, and tools that could be used to understand impacts to birds and bats from offshore wind energy development. Topics of discussion included the following:

- **Cumulative impacts.** It is important to consider cumulative impacts early in the process. This did not occur in Europe and has led to issues as the industry has grown. We need to consider how to approach questions of cumulative effects across state and international boundaries and across the entire annual cycle. Challenges include the use of different methodologies and the variation in population presence across political boundaries, but it is essential to examine the anthropogenic impacts to species along their entire flyways.

- **Collision risk models.** There are ongoing efforts by USFWS and the University of Rhode Island, with funding from BOEM, to create stochastic CRMs specific to listed bird species in the eastern U.S.[33] More generally, while collision risk models are a useful tool for identifying potential risks, there has been limited empirical validation of CRM quantification of risk. We should think about ways to monitor actual collisions in order to validate model predictions and adaptively manage for risk.
- **Risk assessment.** As projects get built, we need to consider how to improve risk assessment tools, including refining models and performing complementary studies to inform our understanding of impacts. Our understanding of terrestrial migrants offshore, in particular, requires improvement; small marine radar systems or other technology deployed on wind turbines could improve our understanding of offshore migration events. Most monitoring tools are limited to periods with good visibility and weather conditions, so our knowledge of offshore movement and distribution patterns may be particularly limited during nighttime and other periods of poor visibility.
- **Utility of the European experience.** The industry is continuing to grow in the UK and across Europe, and with the need to produce more renewable energy and reduce carbon dioxide emissions to mitigate climate change, we will see continued growth in Europe that could help inform our understanding of impacts in the U.S. However, the American offshore wind experience may be somewhat different from that in Europe to date, because of the following factors:
    - U.S. projects are likely to be located farther offshore than early European offshore wind farms. The rapid development of offshore wind turbine technology, particularly in terms of increased turbine size and capacity, means that U.S. projects will also be much larger in scale than early European wind farms.
    - Differences between the U.S. and European regulatory frameworks affect how risk assessments and monitoring will be implemented. In the U.S. there is a strong regulatory focus on potential "take" of ESA-protected species, while European assessments have tended to focus more broadly on the potential for population-level impacts from individual projects.
- **Adequacy of current survey requirements for assessing displacement effects.** Following the current BOEM pre-construction survey guidelines provides adequate information to examine the distribution and abundance of species in the project area. However, the guidelines recommend surveys of the wind farm footprint plus a one nautical mile (nm) buffer, which is an inadequately sized survey area to examine displacement using a BAG study design. For example, if a species of interest has been observed to be displaced 15 km from wind farms, the survey buffer zone may need to be 20 km wide to detect this possible shift in distributions in relation to the wind farm. Currently, we would need to rely on broader-scale baseline information to examine displacement, which is often not collected at an appropriate spatial or temporal scale. In comparison, European projects are often required to survey 4 km or more around projects (Thaxter and Burton 2009, Jackson and Whitfield 2011).

6 Generating Potential Research Questions and Hypotheses

Workshop participants identified a broad range of initial research questions and hypotheses, and then participated in group discussions to expand on initial concepts and begin refining research questions. A detailed summary of these group discussions may be found in appendix E. Key themes that emerged included the following:

- **Designing studies to detect effects.**
  - Some research questions can be answered at the scale of an individual offshore wind project, while others may only be addressed through data aggregation across multiple projects, or by conducting regional-scale studies. Testable hypotheses require identification of an appropriate geographic and temporal scale. Regional-scale questions may be most appropriately addressed through a Regional Wildlife Science Entity (RWSE; there is currently an effort to explore the creation of such an entity[34]).
  - Attributing effects to offshore wind development or other stressors is challenging, particularly with highly migratory species that cross multiple jurisdictions, effects that may vary across the annual cycle, and the potential for carryover effects between life history periods. Population abundance is generally not a sensitive metric for assessing impacts from an anthropogenic stressor. Impacts may manifest through changes to productivity, survival, or other demographic parameters before there are detectable changes in population abundance. We should think critically about the factors driving change, and work to identify other population or ecosystem parameters that may be more informative.
- **Value of different types of questions.**
  - While there are a variety of valid reasons for asking different study questions, we should focus on answering questions that inform future development activities (i.e., strategic projects) as well as questions focused on informing site-specific development decisions. Some questions may have immediate management implications, and for those we need to consider the value of additional information (e.g., will siting, design, or operations be influenced by the answer to the question?). Other research questions may lack immediate management value but provide future benefits in terms of helping to understand cumulative impacts and inform the adaptive management of the industry in the longer term. Collaborative research and funding strategies may be important to help ensure that the latter type of project is prioritized.

- **Reducing uncertainty.**
    - We should consider how research can reduce uncertainty and influence adaptive management, whether to aid in teasing apart effects of different stressors or improving understanding of baseline natural population fluctuations. We need monitoring in place now to understand the use of the marine environment prior to development and be able to identify environmental changes that are due to offshore wind energy activities (see Maclean et al. 2013, Mendel et al. 2019).
- **Importance of data standardization and transparency.**
    - Standardization and transparency of data, including raw data, effort data, and methodological information, are essential to assess the consistency of effects across projects and understand the impacts of development on a biologically relevant spatiotemporal scale.
- **Focal species for research.**
    - Due to the structure of the U.S. regulatory process, applied research and monitoring often focuses on threatened and endangered species. Given their rarity and logistical difficulties associated with obtaining permission to conduct research, however, these species often make poor study subjects. In some cases, a focus on surrogate species may be the best available option to help understand rare species' movements, behaviors, or expected effects of development. However, there is much debate about the utility of surrogate species (Caro et al. 2005, Murphy et al. 2011); small morphological or behavioral differences between species may lead to substantial differences in effects. Suitability of surrogates may depend on similarities in ecological niche between species and the type and scale of question being asked.
    - We should use existing knowledge from Europe to predict which species are likely to exhibit the greatest effects, such as gulls (Thaxter et al. 2019), loons, and gannets, rather than solely focusing on listed species. While species that are sensitive to impacts may not be current regulatory priorities, substantial impacts may lead to future regulatory problems. For instance, terrestrial wind energy development has tended to pose a greater mortality risk and population threat to common, rather than rare, bat species.
    - Additional study candidates could include species or populations with high levels of existing baseline data, those for which we can more easily measure population parameters such as productivity and survival, and/or species designated for conservation concern (such as Species of Greatest Conservation Need[35]).
- **Utility of data from other industries.**
    - Data from the offshore oil and gas industry can help inform offshore wind energy mitigation and discussions of effects, particularly regarding (1) impacts from lighting, (2) end of life of structures and decommissioning, and (3) artificial reef effects.
    - Existing research programs and data from the terrestrial wind energy context can help provide a roadmap for the questions we might ask when approaching pelagic systems.

6.1 Study Methods

Following the identification of a broad range of initial research questions and hypotheses, participants divided into breakout groups to begin more focused development of hypotheses and appropriate study methods. Breakout groups were first organized by general study method (individual tracking, observational surveys, remote sensing, and tissue sampling). Discussions from each breakout group are summarized below into (1) a brief review of the methods discussed, (2) the types of questions those methods are suited to address, and (3) their strengths and limitations. Where groups discussed study methods outside their own topic area, the discussions have been included in the sections of this summary for which they are most topically relevant. These conversations focused on methods for collecting wildlife data, but other types of environmental data (including wind farm operation and weather, oceanographic, and climate data) are also critical to interpreting and understanding wildlife impacts.

6.1.1 Individual Tracking

6.1.1.1 Existing Methods

Visual tracking of birds from boats (also known as focal follows) has been tried in various locations, including for studies of offshore wind impacts on seabirds (for example, Perrow et al. 2011b), but is often quite challenging. More commonly, individual tracking technologies such as automated radio telemetry, GPS telemetry, and satellite telemetry are employed to study the location and movement of individuals (see section 5.4, above; technologies reviewed by Masden n.d.). In the UK, GPS tracking is widely used to study effects from wind farms. Depending on the resolution of the tag and additional integrated sensors, information can be gained related to location, behavior, speed, and flight height (Cleasby et al. 2015, Thaxter et al. 2015, 2018, 2019, Fijn and Gyimesi 2018). Data retrieval approaches vary and include direct download following recapture, remote download via base stations, and GSM transmission. Tracking devices can be attached to animals using a variety of methods, including harnesses, glue mounts, sutures, tape, and surgical implants, each with implications for transmitter longevity and potential effects on the animals carrying them (Geen et al. 2019). The type of tag that can be used is largely driven by the body size of the species of interest (Vandenabeele et al. 2012, Bodey et al. 2018). There are a range of technological advances in the field of individual tracking in recent years, including development of new tracking technologies, integration of additional functionality, and reduction in transmitter and battery size.

6.1.1.2 Types of Questions

Individual tracking technologies provide individual-level movement information on flight paths and behavior in and around wind farms, although in many cases this technology cannot answer questions about interactions with the rotor-swept zone. Tracking can be used to study avoidance and barrier effects, and aid in parameterizing collision risk models. With tracking information before and after construction of wind farms, there is potential to examine displacement. Tracking data also provide opportunities to examine connectivity and sub-population dynamics, aiding in our understanding of potential population-level effects of development.

6.1.1.3 Strengths and Limitations

Tag effect. Some species may be more sensitive to negative effects of tagging than others. For example, a recent study using the same tagging technique on common terns and roseate terns showed more sensitivity to the tags in roseate terns.

Capture. Capture can be challenging, particularly for bats. You must be able to capture individuals during the right time of year so that data represents the time period and location of interest. When capture occurs far from the study area, it may be difficult to know whether individuals will use the area of interest. Reliable recapture of tagged individuals is also required to download data from some types of smaller tags.

Representative sampling. Tagging provides information on the movement of individuals, but it is difficult to ascertain whether movements of these individuals are representative of the wider population. The cost of tags often limits study sample sizes. Limitations relating to tag weight and body size, as well as difficulty of capture, may introduce additional sampling bias based on age class, sex, or other factors.

Potential for additional data collection. Tracking requires capturing birds and bats to deploy tags. Capture represents an opportunity to collect supplementary data, such as body condition and stable isotope data, along with tracking information. There also may be opportunities for integration of multiple sensors or devices to provide additional information beyond latitude and longitude, although these come at the cost of additional tag weight and may require recapture of the animal to retrieve the device. Pressure sensors (which provide altitude and dive-depth information), accelerometers (which provide three-dimensional movement information), and magnetometers (which detect magnetic fields) have been incorporated into some GPS tags. Other types of sensors that may be able to be incorporated into tags include "fitbits" to collect energetic information, as is being explored in the UK. There may be additional opportunities to integrate sensors into automated radio transmitters and other tracking devices, and utilize tags developed for other taxa (such as very small fish tags developed by the Pacific Northwest National Laboratory) for use on birds and bats.

Comparing Automated Radio and GPS Telemetry

- **Species size**—automated radio transmitters are the best (and often the only) option for offshore tracking of small-bodied species, such as bats. GPS telemetry is more flexible, although GPS tag size influences options for data retrieval, with smaller tags requiring direct download (e.g., recapture of the tagged animal to remove the tag) or base station download, both of which limit the tags' utility in the non-breeding season. Smaller GPS units with remote download capabilities are in development but are still limited in what species can carry them.
- **Cost**—automated radio transmitters are relatively inexpensive, allowing for large sample sizes. GPS tags can be considerably more expensive, particularly those that don't require device retrieval.
- **Spatial coverage**—GPS can provide unbiased fine-scale resolution of location information; automated radio telemetry is limited by the network of receiving towers. Expansion of telemetry stations on offshore wind energy infrastructure would help improve offshore coverage and could allow for development of a regional-scale monitoring network in the offshore environment.
- **Flight height**—GPS transmitters can provide good-quality flight height data, although the accuracy of altitude estimates varies. Altitude can be measured using a pressure sensor, which provides good data but requires pressure measurements for calibration. Altitude can also be estimated via the GPS data itself, using the information collecting on the X, Y, and Z axes, but there are pitfalls to this method related to the curvature of the earth and tide height. Uncertainty in estimates also relates to the temporal resolution of GPS fixes. Estimating flight height via triangulation with automated radio transmitters is currently difficult. More precise estimates would require integration with pressure sensors (see above) or accelerometers.

6.1.2 Observational Surveys

6.1.2.1 Existing Methods

The group primarily discussed ship-based, visual aerial, and digital aerial survey approaches.

6.1.2.2 Types of Questions

In general, observational surveys are well-suited to examine avian distribution and abundance and can also provide some behavioral information at specific spatiotemporal scales. Observational surveys are well suited to examine displacement, although displacement studies require surveys to occur beyond the footprint of a development project. Digital aerial surveys have become the preferred method for studying displacement in parts of Europe (methods are discussed in further detail below).

Observational surveys are not generally useful for bats or other nocturnal migrants, nor for understanding directed movements (e.g., migration). Surveys can be used to inform avian collision-related questions by providing flight height data, but there are substantial limitations and caveats in this regard for different survey types, and care must be taken to avoid biased flight height profiles.

6.1.2.3 Strengths and Limitations

Flight Height Data

Flight height assessments from shipboard observers, in which birds are assigned to flight height categories, can be highly inaccurate as well as uncertain (Johnston and Cook 2016). Boat-based surveys intended to produce flight height data should include a dedicated observer with a laser rangefinder (Harwood et al. 2018). Flight height data can also be obtained from digital aerial surveys, but there is uncertainty in altitude estimates—they can be useful for estimating the approximate proportion of birds at collision risk height, but one must be careful not to over-interpret these data.

Distribution and Abundance Data: Boat-Based Surveys

Boat-based surveys are better at assessing distribution and abundance on smaller geographic scales and larger temporal scales than aerial surveys. In particular, they are good for the following:

- Collecting contemporaneous environmental covariate data (e.g., water sampling, proxies for fish abundance, real-time bathymetric data, species composition of forage fish schools, eDNA, multibeam sidescan sonar, etc.) to accompany avian observations.
- Collecting local-scale data such as foraging behavior, foraging hotspots, etc.
- Detecting episodic events (such as migration flights) that require a longer survey period.
- Producing an archive of data, assuming a long-lens camera is used (requires an extra observer).

However, boat-based surveys are seldom used in the UK anymore, because they are:

- Not as economical as digital aerial surveys for covering large survey areas located far offshore. For example, a recent Vineyard Wind project used digital aerial surveys that each took a few hours; whereas boat-based surveys of the same area would have taken seven days to complete.
- More often canceled due to poor weather than digital aerial surveys, which can lead to increased permitting/consenting risk if projects require a certain number of surveys in specific time periods.

- More likely to cause platform effects on animal movements (including both avoidance and attraction), especially if fishing boats are used for surveys.
- Due to the longer time scale of the surveys, they may lead to higher instances of double-counting individuals (Johnston et al. 2015), which violates analytical assumptions.

Distribution and Abundance Data: Aerial Surveys

Aerial surveys produce results that are closer to an instantaneous snapshot of a survey area than boat-based surveys and can often provide greater spatial coverage of an area of interest.

Visual aerial surveys are seldom conducted in the offshore environment, due to concerns with safety, insurance, and platform effects. In Denmark, visual aerial surveys are still conducted at 250 ft above sea level between turbines, but for insurance reasons this is not possible in the UK. Such low-flight altitudes are dangerous to pilots and observers, and cause disturbance and avoidance behaviors in surveyed animals. These surveys also require highly experienced observers to reliably identify species from above and while moving at substantial speeds.

Digital aerial surveys are now required for offshore wind energy development in several European countries due to concerns with visual aerial and boat-based surveys (above). Digital aerial surveys fly higher and faster than visual aerial surveys and are much faster than boat surveys, and thus are particularly well suited (and cost-effective) for surveying larger areas located farther offshore (Buckland et al. 2012). They produce an archive of data for future reference, allowing for robust quality assurance and quality control (QA/QC) procedures. However, they require substantial imagery review time to locate and identify animals. There have been several attempts to develop automated detection and identification algorithms, but there has been limited success for most species to date due to challenges associated with repeatability across surveys. Deep learning neural networks, for example, while effective for a single survey, have been less successfully applied to date across surveys/conditions. USFWS and BOEM are currently exploring digital approaches and deep learning algorithms for future AMAPPS surveys.

Species Identification in Observational Surveys

Detection of small indistinct species such as storm petrels and phalaropes can be difficult in observational surveys. Distinguishing similar species is also a challenge, and visually similar species may be grouped for analysis if necessary (Johnston et al. 2015). Their species distributions may also be differentiated after the fact using various analytical approaches, although if grouped species differ in their identification probability, it can skew the resulting estimated species ratios.

In the eastern U.S., this issue may be most relevant for offshore wind energy development in the context of differentiating roseate terns from common and Arctic terns. An additional observer with a long-lens camera on boat-based surveys can help with species identification after the fact. In the past, identifying roseate terns in aerial digital imagery was more difficult than from a vessel, but APEM and HiDef two leading digital aerial surveying companies) indicated during discussions that they can reliably differentiate roseate terns and common terns.

Data and Training Standards

It is important to identify clear data standards and expected levels of rigor for survey data, and in particular, observer training is required to maintain adequate data standards. BOEM avian survey guidelines for site assessment activities recommend that observers have a certain level of experience. Similarly, the European Seabirds at Sea and Canadian training programs for shipboard observers require demonstration of competence in species identification and survey protocols. The digital aerial survey companies have rigid internal training programs for staff involved with identification and aim to recruit experienced personnel. New observers should be paired with experienced observers during training and deployment. In addition, data collection should be standardized across surveys. Effort data must accompany observational data for analysis, for example, and both European and U.S. survey guidance recommend the use of distance sampling (Buckland et al. 2001, BOEM 2020) for surveys where detection decreases with distance (i.e., boat-based and visual aerial surveys) to allow for bias correction associated with varying detection probabilities (Camphuysen et al. 2004).

Citizen Science Observations

Although not strictly survey data, the use of citizen science data (e.g., collecting anecdotal observations in the offshore environment) was also briefly discussed. There are a large number of marine professionals on the water who could report observations, but some concerns arise about observer bias in relation to offshore wind energy development.

6.1.3 Remote Sensing

6.1.3.1 Existing Methods

Remote sensing technologies that were discussed include acoustics, imaging, radar, and LiDAR (additional remote sensing technologies for collision detection, such as accelerometers and blade-imbedded microphones, also exist). Imaging includes photographic, videographic, thermographic, and satellite data. Radar includes marine and weather surveillance systems. Integration of these remote sensing tools can be valuable, as they often have complementary strengths.

6.1.3.2 Types of Questions

Acoustics can answer questions about site-specific species composition of bats and birds and may potentially provide valuable information about attraction and disorientation (e.g., changes in acoustic activity). Imaging can provide valuable information about flight height, speed, and direction at the project scale, and can also aid in identifying collisions. A programmatic approach could be used for satellite data, such as World View 3 and 4 platforms, to examine distribution and phenology information for marine birds on the sea surface to examine abundance and distribution, hotspots, and staging. Radar can provide data on animal movements at a range of spatial scales, although such data are not species-specific. Smaller-scale marine radar can characterize altitudinal distribution, speed, direction, and density of animals aloft, and may be useful for studying barrier effects. At larger scales, weather surveillance radar can provide information on the relative number, direction, speed, and timing of movement of birds and bats offshore (e.g., BirdCast). LiDAR can be used to estimate flight heights (Cook et al. 2018b), although use of the technology for this purpose is a new application with some limitations.

6.1.3.3 Strengths and Limitations

Strengths and limitations of the discussed technologies are summarized in Table 1.

Table 1. Strengths and Limitations of Remote Sensing Technologies

Technology	Strengths	Limitations
Acoustics	• Useful to study bats, which are difficult to study with most other technologies • Most useful for post-construction monitoring (given platform availability and other considerations) • Can collect data over long periods of time and at night • Relatively low cost • Provides time-stamped presence data (and to a degree, situation-specific absence) that can be correlated with environmental conditions • Many migrant land birds make contact flight calls at night that can be used to improve our understanding of species composition of offshore migrants	• Requires a platform for detector deployment • Challenges with maintaining equipment (e.g., deterioration of microphones), especially in the offshore environment and near the sea surface • Power supply and data storage requirements • Cannot provide true abundance information • Challenging to understand correlations between pre-construction acoustic activity (measured near water's surface) and environmental conditions at nacelle height • Difficult to connect pre-construction acoustic activity to risk • Limitations related to detection range and differentiating contact calls for some avian species
Photo/Video Imagery	• May be used to measure collisions and (because data are timestamped) to understand relationships between covariates/conditions and risk • Useful in examining flight patterns and object size • Useful for examining fine-scale interactions with turbines	• Requires a platform for detector deployment • Tradeoff between field of view and image resolution. Taxonomic classification to species is often difficult • Can be high cost • Challenges in low-visibility conditions • Can be difficult to distinguish collisions from "near-misses" • Possible high level of post-processing of data sets • Challenges with maintaining equipment in offshore environment, as well as power supply and data storage requirements
Satellite Imagery	• Resolution sufficient to detect birds on the water and aggregations in staging areas • Government agencies can utilize the WorldView-3 and-4 platforms at no cost	• Limited utility for smaller, darker species with inferior detectability • Resolution not adequate for identifying many species • Not usable in low visibility conditions • Possible high level of post-processing of data sets
Marine Radar	• Can provide data on passage rates, flight speed, and flight direction • Good altitudinal distribution data • Can allow for target detection and tracking • Moderate cost • Large scale of coverage	• Requires a platform for detector deployment, and may require gyro stabilization offshore • Clutter from water, turbines, and other landscape features can be an issue • Target discrimination can be difficult • Cannot provide species identification (would require pairing with human observers or other technology) • Possible high level of post-processing of data sets
NEXRAD Weather Radar	• Relatively large scale of coverage • Data available in near-real time, providing an opportunity for trigger-based monitoring • Provides a useful index of activity and context for terrestrial migrant movement	• Target discrimination can be difficult • Species identification is not possible • Data cannot be used to directly assess risk • Inference offshore is mostly limited to coastal areas and higher altitudes
LiDAR	• Can provide altitude data and passage-rate data	• Early stages of development for these purposes • Altitude estimates can be biased against low-flying birds due to sea clutter • Very powerful LiDAR required for unbiased flight height profiles • Can be high cost and require possible high level of post-processing of data sets

As all the above technologies have some limitations, integration of multiple technologies can help extend their capabilities. For example, the IdentiFlight[36] system combines visual and thermal cameras. There is also potential for different scales of inference with different technologies, which may allow for more effective study of both exposure and collision risk. Given the cost of many of these systems, it may be beneficial to pool resources for a few large and well-designed studies to use these systems offshore, rather than trying to deploy them at every project.

6.1.4 Tissue Sampling

6.1.4.1 Existing Methods

Blood sampling can be used to understand energetic condition using triglycerides (indicator of fat deposition) and beta-hydroxybutyrate (indicator of fat catabolism), as well as measuring the amount of free-floating fat. Visual measurements as well as weight and wing cord information can provide information on body condition and fat content. Metabolic studies both in the lab and field can contribute to understanding of metabolic rates and energy use. Diet can be examined through the use of eDNA, stomach content (particularly from harvested species), fatty acids, and stable isotope analysis. Stable isotopes can also be used to help determine approximate latitude of origin of migratory species. eDNA water sampling can also be used to assess or predict species presence.

6.1.4.2 Types of Questions

Physiological data can be used to examine the individual and, by extension, the population-level effects of displacement, as well as possible carry-over effects. Combining physiological information with tracking technology can provide information on the effects of displacement on individuals and their prey base to understand how changes in diet may be affecting individual survival and reproduction. Body condition, fat levels, and metabolic rates can be used to understand the possible impacts of barrier effects and displacement. With an understanding of energetic costs throughout the annual cycle, models can be built to examine energetic cost in relation to quality of available resources. Diet information can be used to examine changes in prey availability and the potential energetic effects of changes in nutritional quality of forage, profitability of different resources, and the trophic structure of communities.

6.1.4.3 Strengths and Limitations

- eDNA is a powerful tool but likely cannot aid our understanding of collisions, as presence of eDNA in the water could be attributable to many sources, including predation, scavenging, and defecation.
- These tools provide an opportunity to examine individual-level impacts of displacement and barrier effects. It is difficult to demonstrate causation rather than just correlation, however, and can require baseline information like prey base, individual energetics, body condition, and diet.
- These types of studies require intensive effort, so focused studies on key species may provide inference regarding potential effects for a wider suite of species. Use of surrogate species would likely be needed if the species of interest is endangered.

6.2 Development of Hypotheses

Workshop participants were divided into groups structured around different taxa and types of impacts: avian displacement, collisions, avian attraction and habitat effects, and effects to bats (except for hypotheses requiring direct measurement of collisions). Groups focused on refining the list of brainstormed research questions, developing testable hypotheses, and identifying possible methods based on earlier discussions. These discussions were continued on the third day of the workshop with a smaller group of SMEs; Appendices A-B, who identified additional priority hypotheses and refined the outputs of the earlier breakout groups from the main workshop.

6.2.1 Avian Displacement

The breakout groups ended with five key questions focused on displacement (Table 2). Additional topics of discussion included the following:

- **Barrier effects.** Both the main workshop and SME breakout groups indicated that a hypothesis around barrier effects should be developed, although neither prioritized hypothesis development on this topic during discussions, instead focusing on displacement. It was noted, however, that examining barrier effects would be particularly important for breeding species (specifically central place foragers) that may repeatedly encounter barriers to movement, and for projects located in high-traffic areas.
- **Focal species.** Both the main workshop and SME breakout groups indicated that the choice of focal species is important for displacement studies, and considerations in this regard may vary by region or season. There may be rare species for which we have a strong regulatory need to understand impacts, such as black-capped petrels. It was generally recommended, however, that focal species should include those predicted to exhibit displacement effects, and which are more easily studied, potentially including northern gannets, loons, royal terns, razorbills, diving ducks, and shearwaters.

- **Refining our understanding of displacement.** Displacement can occur in three dimensions (e.g., including altitudinal displacement as well as geographic displacement). GPS tracking studies have also shown that displacement may not occur consistently throughout a wind farm footprint.
- **Pre-construction survey guidelines.** BOEM has a set of pre-construction survey guidelines (BOEM 2020) that help developers determine the types of data to collect pre-construction, but there are no requirements. It was expressed that these guidelines could benefit from an update, including changes to buffer zone size recommendations, to ensure that pre-construction data inform our understanding of effects such as displacement. BOEM indicated that this group and other subject matter experts should provide feedback for improvement.

Table 2. Priority Research Questions Related to Avian Displacement

Blank cells indicate topic areas that were not discussed during breakout groups.

Question	Null Hypothesis	Methods
Are marine birds displaced from wind farms? If so, to what degree?	There is no change in distribution patterns of marine birds that can be attributed to the wind farm.	Project-level pre- and post-construction digital aerial surveys (e.g., BAG design), likely with a minimum of two years of monthly surveys each pre- and post-construction. Study design should include a power analysis to determine necessary survey area, density and spatial coverage of survey lines, and survey frequency. Consider possible level of displacement to determine size of buffer that needs to be surveyed. Surveys could be augmented with GPS tracking data for focal species.
How do changes in distribution from displacement vary geographically?	Changes in distribution patterns are geographically consistent across wind energy areas off the U.S. east coast.	Digital aerial surveys (as above) conducted with consistent methodology across multiple lease areas. Additional survey design considerations are needed, particularly regarding the necessary number of surveys in order to have the power to detect seasonal changes.
Are changes in distributions from displacement temporally consistent?	Changes in distribution patterns are temporally consistent. The level of displacement is consistent at the project site over time (i.e., no habituation occurs).	Regular digital aerial surveys over time to look at changes in distributions, densities, and flight heights. This would also require strategic thinking across projects to look at larger scales. There is potential for collaboration across lease areas.
Does individual behavior of marine birds change from pre- to post-construction?	There is no change in behavior of individuals using the wind farm pre- and post-construction (e.g., change in diving activity, percent of daylight hours foraging, etc.).	Tagging to compare behavior pre- and post-construction (ideal) or within and outside of the wind farm post-construction (although other factors may influence behavior and may not be distinguishable from the effect of the wind farm). GPS tags are ideal for species that can carry this type of tag. Automated radio telemetry may be able to provide useful information but would require a larger network of receivers offshore. Additional considerations include timing, sample size considerations, leveraging existing data, and the collection of auxiliary information (i.e., dive behavior, altitude etc.) where feasible.
What are the population-level impacts of displacement?	There are no population-level impacts of displacement.	Modeling effort to incorporate population dynamics (such as agent-based modeling, if feasible); use resulting model predictions to build hypotheses to test for specific population-level impacts. Data collected from other research, such as movement data, prey information, and activity budgets, can help validate models and develop additional hypotheses.

6.2.2 Collisions

The breakout groups focused on collision-related impacts ended with several key questions (see below), but discussions on this topic were less hypothesis-driven than for other topics. This is in part due to the need for continued technology development and integration to adequately study collision risk, and the degree of current uncertainty in how to accurately measure or predict collision risk. Fundamentally, the key questions to be answered are as follows:

- **What are spatiotemporal patterns of exposure for different species?** A substantial part of conversations in the main workshop and SME breakout groups focused on exposure, as it is measurable now (as opposed to measurement of actual collisions, which must occur post-construction). Multiple questions arose during group discussions such as: What is the spatiotemporal flux of transient migrants offshore? For ESA-listed species like red knots and piping plovers, how much of their migratory path is included in lease areas? (Loring et al. 2018, 2019, 2020). Is there variation in exposure risk related to spatially explicit staging and breeding sites? How does exposure differ based on flight altitude, time of day, season, weather condition, and life history stage?
- **What is the relationship between exposure and collision risk?** Both the main workshop and SME breakout groups recognized that exposure, as estimated via presence or relative abundance over space and time, does not necessarily equate to collision risk. The relationship between exposure and risk may not be consistent across species. Flight height, avoidance rates, and other behavioral information is also important for understanding risk, and ideally should be species- and site-specific.
- **How accurate are collision risk model predictions?** Participants recognized that CRMs have substantial limitations but felt that in the short-term they can help to approximate risk. Pre-construction data should be collected to help parameterize CRMs. Once offshore wind farms are built, collision detection technologies should continue to be developed and deployed to (1) help directly measure risk, (2) validate assumptions about avoidance, flight heights, and other parameters used in in site-specific CRMs, and (3) validate the accuracy of CRM predictions. In particular, rates of macro-, meso-, and micro-avoidance at operational offshore wind projects must be better understood for a variety of taxa under different behavioral and operating conditions.
- **Does the risk of collisions predict a potential population-level effect for any taxa?** Breakout groups indicated that there is value in developing population models in the short term, possibly similar to harvest models, to help understand the scope of population-level effects from offshore wind development that would be detectable (Cook and Robinson 2017, O’Brien et al. 2017).

The SME group recommended that—given the early stage of collision risk monitoring technologies and current knowledge, as well as the likely rarity of collision events—individual project-level, post-construction studies to understand this type of effect may be inefficient and possibly unproductive at this stage. Instead, the group recommended that a first step towards addressing the collision risk issue could be a "gold standard" study to start addressing many of the above questions and inform the development of future hypotheses. This would require large-scale collaborative efforts among researchers, developers, and state and federal agencies, with pre- and post-construction studies at one or a few key study sites. Considerations related to this initial proposed approach included the following:

- The proposed study would be similar to the ORJIP Bird Collision Avoidance Study (Skov et al. 2018) but would likely be larger in scale to focus on multiple taxa (the ORJIP study was focused primarily on seabirds) and potentially include multiple sites.
- A large-scale ORJIP-style study requires substantial resources and may best be pursued through a RWSE.
- The study should examine a range of scales and parameters to both help parameterize CRMs and test the accuracy of CRM predictions.
- Study methods should include some combination of radar, acoustics, GPS tags, and thermal/visual video cameras. The study should also include visual observers with rangefinders to help validate other technologies, assess micro-avoidance, and identify animals to species. Other technologies could include automated radio telemetry to inform movements of small-bodied species, weather radar to study patterns of offshore activity, and strike detectors to help quantify collisions.
- Specialized permit conditions may be needed so that developers have assurance that they will not be punished for successfully detecting collisions and are incentivized (or at least not penalized) to include their wind farm in the study.

6.2.3 Avian Attraction and Habitat Effects

The breakout groups that focused on effects related to habitat change, including artificial reef effects, lighting, and other potential attractants, identified several key questions (Table 3). Additional topics of discussion included the following:

- **Importance of lighting as a possible source of impacts.** Artificial lighting has acted as an attractant in other industries, such as offshore oil and gas (Hope Jones 1980, Hüppop et al. 2006). There was some debate about how relevant this issue might be for offshore wind energy development, given that lighting on turbines is comparatively limited, including flashing red lights on the nacelle and tower (BOEM 2019a), which causes less attraction and disorientation of birds than steady-burning white light (Gehring et al. 2009, Kerlinger et al. 2010). In addition, lighting on turbines is dictated by human safety considerations and thus would be difficult to change even if environmental impacts were detected. BOEM has jurisdiction over turbine lighting in the U.S. for projects located in federal waters (>12 nm from the east coast), and their guidance to date is in line with the Federal Aviation Administration (FAA) and U.S. Coast

Guard requirements for aircraft safety and maritime navigation lighting (BOEM 2019a). Some workshop participants felt that we should assume the potential for lighting-related issues until there is evidence to the contrary. In particular, it was suggested that flood lighting during construction (Poot et al. 2008) and other lighting on boats during construction and maintenance activities (Wiese et al. 2001, Orr et al. 2013) may be more of a concern than lights on turbines.

Table 3. Priority Research Questions Related to Avian Attraction and Habitat Change

Blank cells indicate topic areas that were not discussed during breakout groups.

Question	Null Hypothesis	Methods
What environmental conditions affect attraction of terrestrial, pelagic, and shorebird species to offshore wind turbines?	There is no change in degree of attraction based on environmental conditions.	
Does reducing the amount of time that aircraft safety lighting on turbines is operational (e.g., via the use of Aircraft Detection Lighting Systems or similar) affect the degree of avian attraction that occurs during migration periods?	There is no difference in the amount of attraction that occurs around turbines that use Aircraft Detection Lighting Systems (ADLS) versus those that have their aircraft safety lights on all night.	
Does the introduction of hard structures result in changes in the underwater community in the short-term and long-term?	The introduction of hard structures does not change the underwater community.	Comparison pre- and post-construction of benthic community composition; benthic biomass; forage fish community composition. A temporal gradient design would be needed. A spatial gradient study design may not be necessary, as such changes may be quite local in scale.
Do changes in the underwater community around turbine foundations affect the distribution, abundance, or diet of marine birds?	Changes in the underwater community do not affect the distribution, abundance, or diet of marine birds.	Examine long-term changes in habitats, prey populations, and marine bird abundance/species composition for species that are known to rely on those resources. Both benthic prey (e.g., sand lance, bivalves) and pelagic prey (forage fish) and their respective predators could be examined. Consider a temporal gradient design. Understanding changes in the diet of birds might help disentangle reef effects from other potential effects, such as attraction/displacement due to the presence of physical structures.
How does disturbance of benthic habitat from wind energy construction affect bird abundance/composition, diet, and health in the short term?		Study should be designed to examine short-term effects (i.e., during and immediately after construction) on benthic prey populations, avian abundance and distributions, and avian diet/health.

6.2.4 Impacts to Bats

The breakout groups that focused on impacts to bats identified six key questions (Table 4). On the recommendation of SMEs, the questions take a tiered approach. It was felt that—given what little we know about bats offshore—the first step should be understanding baseline bat activity in the offshore environment before moving to the second step of understanding possible impacts. Collisions were not explicitly addressed by the bat breakout groups, as collision impacts to both birds and bats were discussed elsewhere (section 8.2.2).

Comments from discussions included the following:

- While untested, the current thinking is that drivers of risk to bats offshore are similar onshore. There is likewise a lack of information on the factors that encourage migratory behavior in bats; there may be specific conditions that promote higher levels of offshore movement and thus potentially discrete periods of increased risk. It is possible that the factors driving offshore migration and collision risk are related but may not be the same.
- We may be able to identify a diurnal proxy for bat activity offshore, such as swifts, that could indicate insect abundance offshore. However, it may be easier and more useful to directly measure bat activity (i.e., composition, temporal activity patterns), particularly if acoustic detectors can be deployed at a wide range of projects pre- and post-construction, as they provide the necessary temporal precision (although not spatial precision) with relatively low effort.
- It is important to obtain species-specific information on offshore bat activity where possible. Not all species are equally likely to be present offshore or (based on terrestrial wind energy data) equally likely to interact with turbines, and some species may be at higher risk of population-level impacts.

Table 4. Priority Research Questions Related to Bats

Questions focused on measuring collisions are addressed above (section 8.2.2). Blank cells indicate topic areas that were not discussed during breakout groups.

Question	Null Hypothesis	Methods
What baseline prey resources are available to bats offshore?		Desktop review of offshore nocturnal, aerial, and marine insects and raft species available to bats.
What is baseline bat activity pre-construction in offshore wind project areas?		Opportunistic acoustic monitoring on buoys or boats.
How does bat activity vary throughout the offshore environment?	Bat activity levels are consistent across different distances to shore.	Establish a set of acoustic monitoring linear networks with detectors at varying distances from shore combined with existing coastal data.
How comparable are levels of bat activity at offshore and onshore wind farms?	Bat activity using acoustic detection is similar offshore to onshore projects from coastal states at similar latitudes.	One year of data collection every three years across all seasons using acoustic equipment deployed post-construction at both offshore and onshore wind energy projects; acoustic detectors placed on nacelles; collect environmental correlate (wind speed, humidity, temperature) information.
Does exposure differ offshore versus onshore due to differing environmental conditions?	Exposure offshore is the same as onshore due to similar environmental conditions.	Identify typical offshore and onshore wind operational conditions (wind speed, temperature, etc.) and compare exposure onshore and offshore under differing conditions.
How do offshore wind projects affect the presence, species composition, and activity levels of bats?	The presence of turbines does not change the presence, species composition, and activity levels of bats.	Mobile boat surveys with acoustics, both within and outside of the project area, using a BAG design. Focus on August to October as likely period of highest bat activity.

7 Research Prioritization

The full group of workshop attendees, and then a smaller group of SMEs, discussed how best to prioritize different research questions. There are a range of valid reasons for prioritizing different types of research, depending on what decisions the end results are intended to inform. In no particular order, participants suggested prioritizing studies with the following characteristics and/or concerns:

- **Are feasible and practicable**, based on available methodologies and technology and the scope of the question. We should consider whether the available methods and study design will allow us to satisfactorily test our hypothesis (and be reasonably confident in our answer). It is also important to ensure that well-designed, focused research is incentivized and prioritized during development and permitting processes.
- **Focus on priority species:**
    - Threatened or endangered species or species otherwise identified as high-conservation concern. However, endangered species often make difficult research subjects, so if studying rare species/events, surrogate species should be considered (although the use of surrogate species can be problematic in other ways; see appendix E for additional discussion).
    - Species most likely to be affected, based on local conditions and existing knowledge from Europe. Suggestions from workshop participants included terns and northern gannets. Species with good baseline information on population dynamics and demography can be used to inform our understanding of population-level impacts.
    - Species for which we know little about potential impacts, such as migratory land birds or bats.
    - A tiered approach whereby we continue to focus on species of conservation concern as the first tier, and the second tier focuses on more common species with a great deal of existing information. Some research priorities would likely be different between the two groups but focusing on common species could help fill gaps in understanding and drive the direction of research for endangered species.
- **Inform adaptive management**. There is a benefit to prioritizing studies where the results can inform decisions for future as well as existing projects (whether via permitting decisions, operational implications, mitigation actions, etc.).
- **Address permitting risk**. We may not have enough information to fully understand what issues will represent the greatest permitting risk as the industry develops, but conservation risk and stakeholder concerns are both likely drivers.
- **Focus on certain stressors**. Research should be prioritized based on the stressor with the greatest likely effect or likelihood of causing a population-level decline. The primary stressor of concern may be species-specific.
- **Leverage resources.** Studies that leverage other monitoring or research projects may promote regional coordination and save costs. Cost should not be the primary mechanism for prioritization, but it is important to balance cost against expected benefits.

- **Balance needs at different scales**. There is a trade-off between research with a clear nexus for short-term action (e.g., permitting, mitigation) and broad-scale, population-wide studies that inform many projects in the long term but may not immediately feed into permitting decisions. Both types of research are important to ensure the best long-term outcomes for wildlife and the offshore wind industry.

Subject matter experts indicated that, of the key questions and hypotheses generated during the workshop, the top priorities for new studies could include the following:

- **A large-scale, collaborative collision and avoidance study** similar to the ORJIP Bird Collision Avoidance Study (Skov et al. 2018) to improve understanding of collision risk and inform the development of future hypotheses. This would involve studies pre- and post-construction at one or a few key sites, using some combination of radar, acoustics, GPS tags, thermal/visual video cameras, visual observers with rangefinders, or other methods. As with the ORJIP study, this would likely also require extensive industry collaboration and joint funding. Given the early stage of collision risk monitoring technologies and our current knowledge base on this issue, as well as the likely rarity of collision events, it was felt that at least initially, a coordinated approach to inform our understanding of collision risk and help parameterize CRMs would be more productive than attempting to understand this type of impact on an individual project basis during post-construction monitoring.
- **Large-scale study(ies) of seabird displacement.** SMEs recommended monthly project-level digital aerial surveys for a minimum of two years each pre- and post-construction, although it was emphasized that the survey study design should include a power analysis to determine necessary survey area, density and spatial coverage of survey lines, and survey frequency. It was also emphasized that a larger geographic area would need to be surveyed for any individual project than is currently recommended under the BOEM pre-construction avian survey guidelines (e.g., a 15-20 nm buffer zone may be required in some cases to study the most severely displaced species, as opposed to the 1 nm that is currently in the guidelines). Surveys should be optimized for species of interest (e.g., as identified by expected likelihood of effects and site-level characteristics) and could be augmented with GPS tracking data for focal species.
- **A study of bat activity offshore.** This would involve deployment of acoustic detectors on available offshore platforms, across a gradient of distances from shore and for multiple years, focusing efforts during fall migration. Platforms could include site assessment buoys, vessels, offshore wind turbines, and other infrastructure.

8 Conclusions and Next Steps

Several key themes were identified during workshop discussions, particularly by SMEs during the last day of the workshop. In addition to topic-specific discussions above, the following are overall takeaways from SME discussions:

- All stakeholders in the offshore wind energy development process (including developers, regulators, and scientists) face uncertainty from a variety of sources, including uncertainty related to our scientific understanding of impacts as well as ambiguity in regulatory and decision-making processes (Masden et al. 2015). The ultimate goal of this process of developing short-term and long-term research questions is to help reduce uncertainty as the offshore wind industry moves forward in the U.S. Developing answers to key questions about effects will allow all stakeholders to understand the scope of impacts, and focus adaptive management and further research on the effects of greatest concern. This will hopefully allow for reduction of risk to wildlife populations as well as reduction in permitting and regulatory risk for offshore wind energy projects.
- The first priority for research is to understand effects to wildlife (which may, in some cases, require a better baseline understanding of species' distributions and behaviors in the offshore environment). If we find there are effects, the next steps are to determine (1) what degree of impacts requires mitigation, and (2) how to implement and test mitigation strategies. Mitigation could include site-specific actions, as well as offsets in other areas, particularly for listed species.
- Not every question needs to be asked and answered at every project. We need to consider how best to conduct needed research efficiently, particularly for regionally relevant questions, and be specific as to which questions should be addressed at the site level versus regionally.
- Collaboration will be key to ensure that we are maximizing resources and collecting data to answer long-term and regional-scale questions. In particular, joint efforts may be needed to maximize efficiency, ensure sufficient sample sizes, or develop new and innovative study approaches. Data standardization will also be important as the industry progresses in order to accurately assess cumulative impacts and inform adaptive management of future projects. Standardization of terminology is also important to ensure stakeholders are communicating effectively (appendix F).
- Integration of different technologies and study methods is important to take advantage of each approach's strengths and minimize its limitations. This may be particularly needed regarding the topic of collisions, but there are a range of key questions that could benefit from the development of new study approaches and integration of existing methods.
- Careful study design during the pre-construction period is important to answer some types of questions. Workshop attendees identified an example of this need specific to marine birds. While BOEM has a set of pre-construction avian survey guidelines (BOEM 2020) that help developers determine the types of data to collect pre-construction, many attendees indicated

that these guidelines should be updated to ensure that pre-construction data can be used to better understand effects such as displacement that occur post-construction. Framework leads and SMEs also indicated that they would coordinate with the Atlantic Marine Bird Cooperative's marine spatial planning working group, which is also pursuing this topic, regarding recommendations to BOEM, to update their pre-construction avian survey guidelines.

Building off this workshop, subject matter experts will continue to hone research questions, hypotheses, and methodologies, while developing a scientific research framework document to guide research on the effects of offshore wind development on birds and bats.

9 References

[BOEM] Bureau of Ocean Energy Management. 2019a. Draft proposed guidelines for providing information on lighting and marking of structures supporting renewable energy development. Bureau of Ocean Energy Management Office of Renewable Energy Program, Sterling, VA. 9 pp.

[BOEM] Bureau of Ocean Energy Management. 2019b. Vineyard Wind Offshore Wind Energy Project biological assessment: Final. Report by U.S. Department of the Interior, Bureau of Ocean Energy Management for the U.S. Fish and Wildlife Service. 51 pp.

[BOEM] Bureau of Ocean Energy Management. 2020. Guidelines for providing avian survey information for renewable energy development on the Outer Continental Shelf pursuant to 30 CFR Part 585. U.S. Department of the Interior, Bureau of Ocean Energy Management. 17 pp.

Allison, T. D., J. E. Diffendorfer, E. F. Baerwald, J. A. Beston, D. Drake, A. M. Hale, C. D. Hein, M. M. Huso, S. R. Loss, J. E. Lovich, M. D. Strickland, K. A. Williams, and V. L. Winder. 2019. Impacts to wildlife of wind energy siting and operation in the United States. Issues In Ecology 21:24.

Band, W. 2012. Using a collision risk model to assess bird collision risk for offshore windfarms. report commissioned by The Crown Estate, through the British Trust for Ornithology, via its Strategic Ornithological Support Services, Project SOSS-02. 62 pp.

Bodey, T. W., I. R. Cleasby, F. Bell, N. Parr, A. Schultz, S. C. Votier, and S. Bearhop. 2018. A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. Methods in Ecology and Evolution 9:946–955.

Brabant, R., N. Vanermen, E. W. M. Stienen, and S. Degraer. 2015. Towards a cumulative collision risk assessment of local and migrating birds in North Sea offshore wind farms. Hydrobiologia 756:63–74.

Broadbent, I. D., and C. L. B. Nixon. 2019. Refusal of planning consent for the Docking Shoal offshore wind farm: Stakeholder perspectives and lessons learned. Marine Policy 110:103529.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Buckland, S. T., M. L. Burt, E. A. Rexstad, M. Mellor, A. E. Williams, and R. Woodward. 2012. Aerial surveys of seabirds: The advent of digital methods. Journal of Applied Ecology 49:960–967.

Busch, M., and S. Garthe. 2018. Looking at the bigger picture: The importance of considering annual cycles in impact assessments illustrated in a migratory seabird species. ICES Journal of Marine Science 75:690–700.

Camphuysen, K. C. J., T. A. D. Fox, L. M. F. Mardik, and I. K. Petersen. 2004. Toward standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. COWRIE BAM 02-2002. Report by Royal Netherlands Institute for Sea Research and the Danish National Environmental Research Institute to Crown Estate Commissioners, London, UK. 39 pp.

Caro, T., J. Eadie, and A. Sih. 2005. Use of substitute species in conservation biology. Conservation Biology 19:1821–1826.

Cleasby, I. R., E. D. Wakefield, S. Bearhop, T. W. Bodey, S. C. Votier, and K. C. Hamer. 2015. Three-dimensional tracking of a wide-ranging marine predator: Flight heights and vulnerability to offshore wind farms. Journal of Applied Ecology 52:1474–1482.

Cook, A. S. C. P., E. M. Humphreys, F. Bennet, E. A. Masden, and N. H. K. Burton. 2018a. Quantifying avian avoidance of offshore wind turbines: Current evidence and key knowledge gaps. Marine Environmental Research 140:278–288.

Cook, A. S. C. P., and R. A. Robinson. 2017. Towards a framework for quantifying the population-level consequences of anthropogenic pressures on the environment: The case of seabirds and windfarms. Journal of Environmental Management 190:113–121.

Cook, A. S. C. P., R. M. Ward, W. S. Hansen, and L. Larsen. 2018b. Estimating seabird flight height using LiDAR. Scottish Marine and Freshwater Science 9:66.

Dannheim, J., L. Bergstro, S. N. R. Birchenough, R. Brzana, A. R. Boon, J. W. P. Coolen, J. Dauvin, I. De Mesel, J. Derweduwen, A. B. Gill, L. Hutchison, A. C. Jackson, U. Janas, G. Martin, A. Raoux, J. Reubens, L. Rostin, J. Vanaverbeke, T. A. Wilding, D. Wilhelmsson, and S. Degraer. 2020. Benthic effects of offshore renewables: Identification of knowledge gaps and urgently needed research. ICES Journal of Marine Science 77:1092–1108.

Desholm, M. 2006. Wind farm related mortality – a remote sensing study and model analysis. University of Copenhagen. PhD Thesis. National Environmental Research Institute, University of Copenhagen. 127 pp."

Desholm, M. 2009. Avian sensitivity to mortality: Prioritising migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90:2672–2679.

Dierschke, V., R. W. Furness, and S. Garthe. 2016. Seabirds and offshore wind farms in European waters: Avoidance and attraction. Biological Conservation 202:59–68.

Dirksen, S. 2017. Review of methods and techniques for field validation of collision rates and avoidance amongst birds and bats at offshore wind turbines. Report for Rijkswaterstaat WVL. SjDE 17-01. 47 pp.

Dorsch, M., C. Burger, S. Heinanen, B. Kleinschmidt, J. Morkunas, G. Nehls, P. Quillfeldt, A. Schubert, and R. Zydelis. 2019. DIVER: German tracking study of seabirds in areas of planned Offshore Wind Farms at the example of divers. Final report on the joint project DIVER, FKZ 0325747A/B, funded by the Federal Ministry of Economics and Energy (BMWi) on the basis of a decision by the German Bundestag. FKZ 0325747A/B. Report to the Federal Ministry of Economics and Energy. 282 pp.

Everaert, J., and E. Stienen. 2007. Impact of wind turbines on birds in Zeebrugge (Belgium): significant effect on breeding tern colony due to collisions. Biodiversity and Conservation 163345-3359.

Fijn, R. C., and A. Gyimesi. 2018. Behaviour related flight speeds of Sandwich Terns and their implications for wind farm collision rate modelling and impact assessment. Environmental Impact Assessment Review 71:12–16.

Furness, R. W., H. M. Wade, and E. A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management 119:56–66.

Garthe, S., and O. Hüppop. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41:724–734.

Gartman, V., L. Bulling, M. Dahmen, G. Geißler, and J. Köppel. 2016. Mitigation measures for wildlife in wind energy development, consolidating the state of knowledge — Part 2: Operation, decommissioning. Journal of Environmental Assessment Policy and Management 18:1650014.

Geen, G. R., R. A. Robinson, and S. R. Baillie. 2019. Effects of tracking devices on individual birds – a review of the evidence. Journal of Avian Biology 50:1–14.

Gehring, J., P. Kerlinger, and A. M. Manville. 2009. Communication towers, lights, and birds: Successful methods of reducing the frequency of avian collisions. Ecological Applications 19:505–514.

Harwood, A. J. P., M. R. Perrow, and R. J. Berridge. 2018. Use of an optical rangefinder to assess the reliability of seabird flight heights from boat-based surveyors: Implications for collision risk at offshore wind farms. Journal of Field Ornithology 89:372–383.

Hope Jones, P. 1980. The effect on birds of a North Sea gas flare. British Birds 73:547–555.

Hüppop, O., J. Dierschke, K. M. Exo, E. Fredrich, and R. Hill. 2006. Bird migration studies and potential collision risk with offshore wind turbines. Ibis 148:90–109.

Inger, R., M. J. Attrill, S. Bearhop, A. C. Broderick, W. James Grecian, D. J. Hodgson, C. Mills, E. Sheehan, S. C. Votier, M. J. Witt, and B. J. Godley. 2009. Marine renewable energy: Potential benefits to biodiversity? An urgent call for research. Journal of Applied Ecology 46:1145–1153.

Jackson, D., and P. Whitfield. 2011. Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 4. Birds. Report to Scottish Natural Heritage and Marine Scotland. 95 pp.

Johnston, A., and A. S. Cook. 2016. How high do birds fly? Development of methods and analysis of digital aerial data of seabird flight heights. BTO Research Report No. 676. Report by the British Trush for Ornithology to Natural England and The Crown Estate, Thetford, U.K. 53 pp.

Johnston, A., A. S. C. P. Cook, L. J. Wright, E. M. Humphreys, and N. H. K. Burton. 2014. Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology 51:31–41.

Johnston, A., C. B. Thaxter, G. E. Austin, A. S. C. P. Cook, E. M. Humphreys, D. A. Still, A. Mackay, R. Irvine, A. Webb, and N. H. K. Burton. 2015. Modelling the abundance and distribution of marine birds accounting for uncertain species identification. Journal of Applied Ecology 52:150–160.

Kerlinger, P., J. L. Gehring, W. P. Erickson, R. Curry, A. Jain, and J. Guarnaccia. 2010. Night migrant fatalities and obstruction lighting at wind turbines in North America. The Wilson Journal of Ornithology 122:744–754.

Kraus, S. D., R. D. Kenney, and L. Thomas. 2019. A framework for studying the effects of offshore wind development on marine mammals and turtles. Report to the Massachusetts Clean Energy Center and the Bureau of Ocean Energy Management. 48 pp.

Krijgsveld, K. L., K. Akershoek, F. Schenk, F. Dijk, and S. Dirksen. 2009. Collision risk of birds with modern large wind turbines. Ardea 97:357–366.

Lagerveld, S., D. Gerla, J. T. van der Wal, P. de Vries, S. Brabant, E. Stienen, K. Deneudt, J. Manshanden, and M. Scholl. 2017. Spatial and temporal occurrence of bats in the southern North Sea area. Research Report C090/17. Report by Wageningen University and Research. 52 pp.

Leopold, M. F. 2018. Common Guillemots and offshore wind farms: an ecological discussion of statistical analyses conducted by Alain Zuur. Research Report C093/18. Report by Wagening University and Research. 16 pp.

Leopold, M. F., E. M. Dijkman, L. Teal, and OWEZ-Team. 2011. Local Birds in and around the Offshore Wind Farm Egmond aan Zee (OWEZ). Report nr. C187/11. Report for NoordzeeWind by the Institute for Marine Resources & Ecosystem Studies. 176 pp.

Loring, P. H., J. D. Mclaren, H. F. Goyert, and P. W. C. Paton. 2020. Supportive wind conditions influence offshore movements of Atlantic Coast Piping Plovers during fall migration. The Condor 122:1–16.

Loring, P.H., P.W.C. Paton, J.D. McLaren, H. Bai, R. Janaswamy, H.F. Goyert, C.R. Griffin, and P.R. Sievert. 2019. Tracking offshore occurrence of Common Terns, endangered Roseate Terns, and threatened Piping Plovers with VHF arrays. OCS Study BOEM 2019-017. US Department of the Interior, Bureau of Ocean Energy Management, Sterling, VA. 140 pp.

Loring, P., J. McLaren, P. Smith, L. Niles, S. Koch, H. Goyert, and H. Bai. 2018. Tracking movements of threatened migratory rufa Red Knots in U.S. Atlantic Outer Continental Shelf Waters. OCS Study BOEM 2018-046. US Department of the Interior, Bureau of Ocean Energy Management, Stirling, VA. 145 pp.

De Lucas, M., G. F. E. Janss, D. P. Whitfield, and M. Ferrer. 2008. Collision fatality of raptors in wind farms does not depend on raptor abundance. Journal of Applied Ecology 45:1695–1703.

MacLean, I. M. D., M. M. Rehfisch, H. Skov, and C. B. Thaxter. 2013. Evaluating the statistical power of detecting changes in the abundance of seabirds at sea. Ibis 155:113–126.

Maclean, I., M. M. Rehfisch, H. Skov, and C. B. Thaxter. 2013. Evaluating the statistical power of detecting changes in the abundance of seabirds at sea. Ibis 155:113–126.

Masden, E. (n.d.). Review of telemetry technologies in relation to the marine renewable energy sector and seabirds. Environmental Research Institute North Highland College. University of the Highlands and Islands, Thurso, Scotland. 11 pp.

Masden, E. A., and A. S. C. P. Cook. 2016. Avian collision risk models for wind energy impact assessments. Environmental Impact Assessment Review 56:43–49.

Masden, E. A., D. T. Haydon, A. D. Fox, and R. W. Furness. 2010. Barriers to movement: Modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. Marine Pollution Bulletin 60:1085–1091.

Masden, E. A., D. T. Haydon, A. D. Fox, R. W. Furness, R. Bullman, and M. Desholm. 2009. Barriers to movement: Impacts of wind farms on migrating birds. ICES Journal of Marine Science 66:746–753.

Masden, E. a., A. McCluskie, E. Owen, and R. H. W. Langston. 2015. Renewable energy developments in an uncertain world: The case of offshore wind and birds in the UK. Marine Policy 51:169–172.

McGregor, R. M., S. King, C. R. Donovan, B. Caneco, and A. Webb. 2018. A stochastic collision risk model for seabirds in flight. HC0010-400-001. Report by HiDef and BioConsult SH to Marine Scotland. 59 pp

Mendel, B., P. Schwemmer, V. Peschko, S. Müller, H. Schwemmer, M. Mercker, and S. Garthe. 2019. Operational offshore wind farms and associated ship traffic cause profound changes in distribution patterns of Loons (*Gavia* spp.). Journal of Environmental Management 231:429–438.

Methratta, E. T., and W. R. Dardick. 2019. Meta-Analysis of Finfish Abundance at Offshore Wind Farms. Reviews in Fisheries Science and Aquaculture 27:242–260.

Murphy, D. D., P. S. Weiland, and K. W. Cummins. 2011. A Critical Assessment of the Use of Surrogate Species in Conservation Planning in the Sacramento-San Joaquin Delta, California (U.S.A.). Conservation Biology 25:873–878.

Newton, I., and B. Little. 2009. Assessment of wind-farm and other bird casualties from carcasses found on a Northumbrian beach over an 11-year period. Bird Study 56:158–167.

O’Brien, S. H., A. S. C. P. Cook, and R. A. Robinson. 2017. Implicit assumptions underlying simple harvest models of marine bird populations can mislead environmental management decisions. Journal of Environmental Management 201:163–171.

Orr, T., S. Herz, and D. Oakley. 2013. Evaluation of lighting schemes for offshore wind facilities and impacts to local environments. OCS Study BOEM 2013-0116. U.S. Department of the Interior, Bureau of Ocean Energy Management, Herndon, VA. 429 pp.

Perrow, M. R., J. J. Gilroy, E. R. Skeate, and M. L. Tomlinson. 2011a. Effects of the construction of Scroby Sands offshore wind farm on the prey base of Little tern *Sternula albifrons* at its most important UK colony. Marine Pollution Bulletin 62:1661–70.

Perrow, M. R., E. R. Skeate, and J. J. Gilroy. 2011b. Visual tracking from a rigid-hulled inflatable boat to determine foraging movements of breeding terns. Journal of Field Ornithology 82:68–79.

Petersen, I. K., T. K. Christensen, J. Kahlert, M. Desholm, and A. D. Fox. 2006. Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark. Report by The National Environmental Research Institute to DONG energy and Vattenfall A/S. 161 pp.

Petersen, I. K., R. D. Nielsen, and M. L. Mackenzie. 2014. Post-construction evaluation of bird abundances and distributions in the Horns Rev 2 offshore wind farm area, 2011 and 2012. Report by The National Environmental Research Institute to DONG energy and Vattenfall A/S. 161 pp.

Pettersson, J. 2005. The impact of offshore wind farms on bird life in Southern Kalmar Sound Sweden final report based on studies 1999-2003. Report by the Department of Animcal Ecology, Lund University, Sweden for the Swedish Energy Agency. 124 pp.

Plonczkier, P., and I. C. Simms. 2012. Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. Journal of Applied Ecology 49:1187–1194.

Poot, H., B. J. Ens, H. de Vries, M. A. H. Donners, M. R. Wernand, and J. M. Marquenie. 2008. Green light for nocturnally migrating birds. Ecology & Society 13:47.

Russell, R. W. 2005. Interactions between migrating birds and offshore oil and gas platforms in the northern Gulf of Mexico: Final report. OCS Study MMS 2005-009. U.S. Department of the Interior, Minerals Management Service, New Orleans, LA. 348 pp.

Schirmacher, M. 2020. Evaluating the effectiveness of an ultrasonic acoustic deterrent in reducing bat fatalities at wind energy facilities. DOE-BCI-0007036. Report by Bat Conservation International to Department of Energy Office of Energy Efficiency and Renewable Energy. 124 pp.

Searle, K. R., D. C. Mobbs, A. Butler, R. W. Furness, M. N. Trinder, and F. Daunt. 2018. Finding out the fate of displaced birds. Scottish Marine and Freshwater Science 9(8):1-161.

Skov, H., S. Heinanen, T. Norman, R. M. Ward, S. Mendez-Roldan, and I. Ellis. 2018. Report by NIRAS and DHI to The Carbon Trust, U.K. 247 pp.

Slavik, K., C. Lemmen, W. Zhang, O. Kerimoglu, K. Klingbeil, and K. W. Wirtz. 2019. The large scale impact of offshore wind farm structures on pelagic primary productivity in the southern North Sea. Hydrobiologia 845:35–53.

Spiegel, C. S., A. M. Berlin, A. T. Gilbert, C. O. Gray, W. A. Montevecchi, I. J. Stenhouse, S. L. Ford, G. H. Olsen, J. L. Fiely, L. Savoy, M. W. Goodale, and C. M. Burke. 2017. Determining fine-scale use and movement patterns of diving bird species in federal waters of the Mid-Atlantic United States using satellite telemetry. OCS Study BOEM 2017-069. Bureau of Ocean Energy Management. Sterling, VA. 293 pp.

Stantec Consulting Services Inc. 2016. Long-term bat monitoring on islands, offshore structures, and coastal sites in the Gulf of Maine, mid-Atlantic, and Great Lakes - Final Report. Prepared for the U.S Department of Energy, Topsham, ME. 171 pp.

Thaxter, C. B., and N. H. K. Burton. 2009. High definition imagery for surveying seabirds and marine mammals: A review of recent trials and development of protocols. Report by the British Trust for Ornithology Report for Cowrie Ltd. 30 pp.

Thaxter, C. B., G. J. Conway, N. H. K. Burton, V. H. Ross, S. Willem, E. A. Masden, N. A. Clark, G. D. Clewley, L. J. Barber, and C. B. Thaxter. 2019. Avian vulnerability to wind farm collision through the year: Insights from lesser black-backed gulls (*Larus fuscus*) tracked from multiple breeding colonies. Journal of Applied Ecology:1–13.

Thaxter, C. B., V. H. Ross-Smith, and W. Bouten. 2015. Seabird – wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull *Larus fuscus* in the UK. Biological Conservation 186:347–358.

Thaxter, C. B., V. H. Ross-Smith, W. Bouten, E. A. Masden, N. A. Clark, G. J. Conway, L. Barber, G. D. Clewley, and N. H. K. Burton. 2018. Dodging the blades: New insights into three-dimensional space use of offshore wind farms by lesser black-backed gulls *Larus fuscus*. Marine Ecology Progress Series 587:247–253.

Trinder, M. 2016. Beatrice Offshore Wind Farm pre-construction aerial survey report. LF000005-REP-690. Report by Beatrice Offshore Windfarm Ltd. 61 pp.

Vandenabeele, S. P., E. L. Shepard, A. Grogan, and R. P. Wilson. 2012. When three per cent may not be three per cent; device-equipped seabirds experience variable flight constraints. Marine Biology 159:1–14.

Vanermen, N., W. Courtens, R. Daelemans, L. Lens, W. Müller, M. Van De Walle, H. Verstraete, and E. W. M. Stienen. 2020. Attracted to the outside: A meso-scale response pattern of lesser black-backed gulls at an offshore wind farm revealed by GPS telemetry. ICES Journal of Marine Science 77:701–710.

Vanermen, N., T. Onkelinx, W. Courtens, M. Van de walle, H. Verstraete, and E. W. M. Stienen. 2015a. Seabird avoidance and attraction at an offshore wind farm in the Belgian part of the North Sea. Hydrobiologia 756:51–61.

Vanermen, N., T. Onkelinx, P. Verschelde, W. Courtens, M. Van de walle, H. Verstraete, and E. W. M. Stienen. 2015b. Assessing seabird displacement at offshore wind farms: power ranges of a monitoring and data handling protocol. Hydrobiologia 756:155–167.

Vilela, R., F. Bachl, and A. Diederichs. 2019. Assessing the effect of windfarms on marine mammals using point pattern analysis. Poster by Bio Consult SH and HiDef Aerial Surveying Limited. 1 pp.

Welcker, J., and G. Nehls. 2016. Displacement of seabirds by an offshore wind farm in the North Sea. Marine Ecology Progress Series 554:173–182.

Wiese, F. K., W. A. Montevecchi, G. K. Davoren, F. Huettmann, A. W. Diamond, and J. Linke. 2001. Seabirds at risk around offshore oil platforms in the Northwest Atlantic. Marine Pollution Bulletin 42:1285–1290.

Wilding, T. A., A. B. Gill, A. Boon, E. Sheehan, J. C. Dauvin, J. P. Pezy, F. O'Beirn, U. Janas, L. Rostin, and I. De Mesel. 2017. Turning off the DRIP ('Data-rich, information-poor') – rationalising monitoring with a focus on marine renewable energy developments and the benthos. Renewable and Sustainable Energy Reviews 74:848–859.

Wilhelmsson, D., and T. Malm. 2008. Fouling assemblages on offshore wind power plants and adjacent substrata. Estuarine, Coastal and Shelf Science 79:459-466.

Willmott, J. R., G. Forcey, and A. Kent. 2013. The relative vulnerability of migratory bird species to offshore wind energy projects on the Atlantic Outer Continental Shelf: An assessment method and database. OCS Study BOEM 2013-207. Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. 275 pp.

Winship, A., B. Kinlan, T. White, J. Leirness, and J. Christensen. 2018. Modeling At-Sea Density of Marine Birds to Support Atlantic Marine Renewable Energy Planning. BOEM OCS 2018-010. Report to the U.S. Department of the Interior, Bureau of Ocean Energy Managment, Stirling, VA. 67 pp.

Zipkin, E. F., B. P. Kinlan, A. Sussman, D. Rypkema, M. Wimer, and A. F. O'Connell. 2015. Statistical guidelines for assessing marine avian hotspots and coldspots: A case study on wind energy development in the U.S. Atlantic Ocean. Biological Conservation 191:216–223.

Appendix A: Final Agenda

March 4, 2020

9:00-10:15 am	Purpose and Context
	Welcome and Introductions *Kate McClellan Press, NYSERDA*
	Research Framework Purpose and Scope *Kate Williams, Biodiversity Research Institute*
	Workshop Design and Participation Ground Rules *Pat Field, Consensus Building Institute*
	Regulatory and Development Context *David Bigger, Bureau of Ocean Energy Management*
	Offshore Wind Developers Perspective *Various*
	Q&A
10:15 am- 12:55 pm	Overview of Current Knowledge
	European Review: Seabird Displacement and Barrier Effects *Ib Krag Petersen, Aarhus University*
	European Review: Seabirds and Collision Risk *Aonghais Cook, British Trust for Ornithology*
	BREAK (15 min)
	Seabird Distribution and Abundance Data *Arliss Winship, NOAA NCCOS & CSS*
	Seabird Movements and Finer-scale Habitat Associations in the Northwest Atlantic *Pam Loring, U.S. Fish & Wildlife Service*
	Migration of Terrestrial Birds in the Offshore Environment *Andrew Farnsworth, Cornell Lab of Ornithology*
	Bats and Offshore Wind *Trevor Peterson, Stantec*
	Q&A & Discussion
12:55-1:30 pm	LUNCH

1:00-5:30 pm	Developing Hypotheses and Identifying Study Methods
	Overview of Data Collection Methods: Displacement, Barrier effects, Habitat effects *Andy Webb, HiDef Aerial Surveying*
	Existing, New, and Emerging Technologies for Measuring Collisions *Jocelyn Brown-Saracino, Department of Energy*
	Analytical and Statistical Approaches for Testing Hypotheses *Andrew Farnsworth, Cornell Lab of Ornithology*
	Discussion: Generating Potential Research Questions and Hypotheses
	BREAK (30 min)
	Preliminary Review of Hypotheses/Questions
	Discussion of existing data and potential methods for hypothesis-testing
	Reflections on Day 1 and Overview of Day 2

March 5, 2020

9:00-9:15 am	Review and Synthesis of Day 1 *Pat Field, Consensus Building Institute*
9:15-11:00 am	Preliminary Experimental Design for Hypotheses
	Collisions
	Behavioral and Physiological Change
	Q&A
	BREAK (15 min)
11:00 am- 12:30 pm	Further Development of Hypotheses and Study Methods: Round 1
	Breakout Groups by Type of Effect *The aim of this first breakout is to define hypotheses and potential methods, including defining the relevant development phase, study taxa, impact to be measured, and study methods.*
	Report Back and Group Discussion
12:30-1:30 pm	LUNCH
1:30-3:15 pm	Further Development of Hypotheses and Study Methods: Round 2
	Breakout Groups by Study Method *The aim is to take the outputs from the first round of breakout groups and divide by study method to discuss whether hypotheses are testable based on available methods and to discuss study design.*
	Q&A & Discussion
	BREAK (15 min)
3:15-4:30 pm	Final Discussion

March 6, 2020—Subject Matter Expert Committee Discussion

Time	Topic	Description
9:00-9:15	Introduction	Review of goals for the day and outcomes from the March 4-5 workshop
9:15-10:15	Filling in Gaps—Group Discussion	Review of workshop hypotheses/questions: is anything missing? What topics need further refinement?
10:15-10:30	BREAK	
10:30-11:30	Breakout Groups	For topics identified above, break out into groups to continue discussions (including refining new hypotheses, if any, and identifying potential study design and methods considerations for hypotheses that were not fully fleshed out in Days 1-2 of the workshop)
11:30-12:00	Report Back and Group Discussion	Refine list of hypotheses and methods considerations
12:00-1:00	LUNCH	
1:00-2:00	Hypothesis Testability and Prioritization	Discussion of prioritization of research questions
3:00-3:30	Final Discussion	Review next steps for drafting the framework document

Appendix B: List of Participants

Attendees listed in bold are subject matter experts that participated in the third day of discussions (March 6) following the main workshop.

Name	Affiliation
Andrew Farnsworth*	Cornell Lab of Ornithology
Andy Webb	HiDef Aerial Surveying
Aonghais Cook	British Trust for Ornithology
Arliss Winship	CSS Inc. – contractor to NOAA National Centers for Coastal Ocean Science
Brita Woeck	Ørsted
Carolyn Mostello	Massachusetts Division of Fisheries and Wildlife
Catherine Bowes	National Wildlife Federation
Chris Guy	U.S. Fish and Wildlife Service
Clara Cooper-Mullin	University of Rhode Island
Corrie Folsom O'Keefe	Audubon Connecticut
Cris Hein	National Renewable Energy Laboratory
Curtis Smalling	Audubon North Carolina
David Allen	North Carolina Wildlife Resources Commission
David Bigger	Bureau of Ocean Energy Management
David Mizrahi	New Jersey Audubon
David Phillips	Equinor
Elizabeth Craig	Shoals Marine Laboratory, University of New Hampshire
Emily Argos	U.S. Fish and Wildlife Service
Garry George	National Audubon Society
Genevra Harker-Klimeš	Pacific Northwest National Laboratory
Holly Goyert	CSS Inc. – contractor to NOAA National Centers for Coastal Ocean Science
Iain Stenhouse	Biodiversity Research Institute
Ib Krag Petersen	Aarhus University
Jennifer Stucker	Western EcoSystems Technology, Inc.
Jillian Liner	Audubon New York
Joan Walsh	Massachusetts Audubon
Jocelyn Brown-Saracino	U.S. Department of Energy
Julia Gulka*	Biodiversity Research Institute
Julia Wilmott	Normandeau Associates
Kate McClellan Press*	New York State Energy Research and Development Authority
Kate Williams*	Biodiversity Research Institute
Linda Welch	U.S. Fish and Wildlife Service
Louis Brzuzy	Shell New Energies
MacKenzie Hall	New Jersey Department of Environmental Protection
Mao Lin	Tetra Tech

Name	Affiliation
Matthew Robertson	Vineyard Wind
Michael Whitby	Bat Conservation International
Naomi Lewandowski	U.S. Department of Energy
Pam Loring	U.S. Fish and Wildlife Service
Robb Diehl	United States Geological Service
Patrick Field*	Consensus Building Institute
Scott Johnston	U.S. Fish and Wildlife Service
Sherryll Huber Jones	New York State Department of Environmental Conservation
Steven Papa	U.S. Fish and Wildlife Service
Susi von Oettingen	U.S. Fish and Wildlife Service
Taber Allison	American Wind Wildlife Institute
Timothy White	Bureau of Ocean Energy Management
Trevor Peterson	Stantec

* Workshop organizers and facilitation team

Appendix C: Discussion from the Overview of Current Knowledge Session

Panelists: Ib Krag Petersen (Aarhus University), Aonghais Cook (British Trust for Ornithology), Arliss Winship (CSS Inc. and NOAA NCCOS), Pam Loring (USFWS), Andrew Farnsworth (Cornell Lab of Ornithology), Trevor Peterson (Stantec).

This plenary session focused on reviewing existing research and scientific knowledge on offshore wind energy's impacts to birds and bats. Topics addressed in Q&A periods, as well as additional detail provided by speakers on certain topics, have been summarized below.

- **Methods for displacement studies.** The German displacement studies that were discussed used a combination of visual aerial and digital aerial surveys; the Danish study used visual aerial surveys. In general, surveys were conducted monthly, and spatial models were built to develop monthly density estimates which were then averaged and compared. Visual survey approaches use a distance sampling method that corrects for lower detectability of birds at greater distances from the observer and can also account for differences in observations due to factors such as observer identity and visibility conditions.
- **Effect of turbine spacing on displacement.** Studies demonstrating displacement in red-throated loons had a turbine spacing of 800 m. A study from the Netherlands that examined the effect of turbine spacing on displacement found less displacement with greater spacing between turbines.
- **Effect of boat traffic on displacement.** It would be ideal to get boat traffic information from offshore wind companies for incorporation into studies of disturbance/displacement, but (at least in Europe) they seldom make such data accessible to researchers. Digital aerial surveys may provide some boat density data as well.
- **Habituation.** There is little impetus in the European Union to perform displacement studies on a time scale that could examine habituation for most species, as surveying regularly at a long enough interval to demonstrate habituation would require a great deal of time, money, and effort.
- **Life cycle impacts of displacement.** We would like to improve our understanding of dynamics for the entire life cycle of displaced seabirds, but many are Arctic breeders that are displaced during the nonbreeding season, which makes tracking effects throughout the annual cycle challenging.
- **Parameters in collision risk models.** Model parameters include both turbine variables (number of turbines, spacing, hub height, rotor radius, maximum blade width, rotation speed), and species-specific variables (bird density, avoidance rate, percent nocturnal activity, bird length, wingspan, flight height, flight speed). Wind wake at wind farms has not been considered in models to date, but could be worth investigating further, as it likely influences bird behavior.

- **Avoidance and collision risk.** Avoidance occurs at a variety of scales: macro-avoidance, when a bird does not enter the wind farm footprint; meso-scale avoidance, when birds within the wind farm avoid the actual turbines; and micro-scale ("last second") avoidance when birds in the immediate vicinity of a turbine implement evasive maneuvers to avoid a collision (Cook et al. 2018a). Avoidance is difficult to measure and predict as it occurs at this variety of scales and in multiple dimensions. For example, a recent study examined three-dimensional behavior of lesser black-backed gulls at a wind farm and found strong avoidance of the rotor-swept zone, but potential attraction to the bases of turbines (Thaxter et al. 2018).
- **Collision mitigation.** A commonly recommended measure to reduce collision risk to marine birds in the UK is to raise the altitude of the lower edge of the rotor-swept zone, as hub height is directly related to mortality estimates in collision risk models for many seabirds that tend to fly near the water's surface (Krijgsveld et al. 2009, Johnston et al. 2014, Gartman et al. 2016). Combined with increasing turbine size, it is possible that collision risk could be reduced while also increasing energy production. There is little, if any, empirical evidence that this measure reduces collision risk, however. Improving our understanding of high-risk time periods could potentially inform other mitigation strategies, such as curtailment, although these have not been implemented offshore for birds to date.
- **Collision risk for migratory land birds.** There is a variant of the Band Model specifically for migrants that includes assumptions around flux rates. Predicted risk tends to be low for individual projects in Europe, although given the large scale of planned offshore wind energy development in the region, cumulative risk may eventually become an issue.
- **Collision risk for migratory seabirds.** CRM efforts in the UK tend to focus on the nation's internationally important breeding seabird populations, although CRMs utilize density estimates that encompass winter and migratory seasons as well as breeding season information. To improve collision risk models, we need information on migratory routes using tracking. Currently, most GPS data is from the breeding season, but migration data should also be collected and incorporated into models.
- **Re-assessment of collision risk using new parameter estimates.** There has been some interest in revisiting CRM estimates from older projects in the UK to reassess potential cumulative risk. A few attempts have had varying levels of acceptance from stakeholders, and there will likely be more work in this area in the future. We commonly lack both information on study methodology and accessible raw data from older projects, thus making reanalysis challenging.
- **Predicting seabird distributions in the eastern U.S using environmental covariates.** The importance of different covariates varies by species and season. Generally, bathymetry is an important variable, along with other variables that represent the inshore-offshore gradient. Covariate data quality can be problematic for modeling, particularly at fine spatiotemporal scales.
- **Application of automated radio telemetry for monitoring at offshore wind projects.** Once infrastructure is in the water, there is an opportunity to co-locate tracking equipment with turbines, and there is huge potential to monitor a large and diverse sample of wildlife. NYSERDA recently funded a project to provide guidance to offshore wind developers for incorporating automated radio telemetry into their pre- and post-construction monitoring plans, including an online study design tool to help optimize detections.

- **Capabilities of automated radio tracking technology.** Receiver antennas are directional and record signal strength, so when a tag is detected, it provides information on bearing and relative distance to the receiver. Deriving altitude information requires simultaneous detections at multiple towers and using the relationship between detection range and height to estimate altitude.
- **Offshore movements of listed shorebirds.** BOEM-funded tracking work on piping plovers and red knots over the last several years has found that piping plovers tagged during fall migration often flew across the Mid-Atlantic Bight to staging areas in New Jersey and North Carolina. At least 40% of the population winters in the Bahamas, so they are clearly making sustained offshore flights, with potential exposure to lease areas. There are two populations of red knots: short-distance migrants that cut across the Mid-Atlantic Bight, and longer-distance migrants that head straight offshore. Coarse estimates of flight heights suggest that both piping plovers and red knots were flying approximately 350 m above sea level. There is a gap in knowledge for spring migration.
- **Using eBird data to understand offshore movements.** eBird is a citizen science platform that currently has three-quarters of a billion observations, including observations from pelagic birding trips and other offshore birding opportunities as well as coastal observations. However, location data for many of these offshore observations is limited; it is important to consider the limitations of these data and determine how best to use them.
- **Characteristics of offshore movements of terrestrial migrants.** Along the Atlantic coast, strong westerly and northwesterly winds at ≥7 m/s during fall migration will bring terrestrial migrants offshore. There is not necessarily a reduction in migration activity above a certain wind speed, as is seen in bats, although this is location dependent. Onshore, birds migrate during a variety of conditions; unless there is a strong headwind, birds are likely aloft. While we have some altitudinal information for migration from terrestrial radars, we lack this kind of information farther offshore.
- **Uses of NEXRAD weather radar for studying offshore migration and informing mitigation.** The offshore coverage of weather radar is very limited, but it is possible that data can be used to understand when birds might enter an offshore area, from what direction, and under what conditions. Migration prediction forecasts are fairly accurate within a one- to three-day window, and are updated every 6 hours, so it is possible to extract this biological signal in near-real time and use it for management purposes, such as informing lighting-related mitigation strategies.
- **Bat telemetry.** The Motus Network includes some bat data, but for purposes of informing our knowledge of offshore movements, it is challenging to tag bats during the right time of year to capture extended movements. Automated radio telemetry with eastern red bats and northern long-eared bats in early autumn showed greater levels of movement among red bats. Small GPS tags show promise for larger species such as hoary bats.
- **Bat attraction to offshore structures.** There is potential for offshore structures such as buoys and oil platforms to attract bats, as they may represent roosting opportunities, but we do not understand the scale at which such attraction might be occurring.

- **Characteristics of onshore bat migration.** We know less about bat migration than bird migration. The best resource we currently have is museum specimens. We also have some information from fatalities at terrestrial wind facilities. Generally, migratory tree bats migrate from Canada to the southeastern U.S. They appear to move throughout most of the continental U.S. during fall migration (e.g., in more of a broad front than a concentrated flyway).
- **Characteristics of offshore bat migration.** Most opportunities for acoustic monitoring are near shore, making it difficult to assess offshore bat movement. However, bats are adapted to fly long distances and forage while flying, and recent digital aerial surveys from the eastern U.S. detected bats up to 50 miles offshore. Information on insect migration is limited, but the strong association between bats and wind speed likely relates to prey base, and this in turn is likely an important factor contributing to bat presence offshore.
- **Limitations of passive acoustics to understand bat movements offshore.** It is difficult to get abundance information from acoustic data, and acoustic equipment does not hold up well in the marine environment long term, particularly when deployed on buoys. Post-construction deployment on permanent infrastructure such as turbines may be more effective than deployment on buoys during the site assessment period.
- **Relevant databases.** Offshore bird survey data is stored in the Northwest Atlantic Seabird Catalog; the American Wind Wildlife Institute has a database of bird and bat fatality monitoring data; bat acoustic data is stored in the BatAMP data portal;[37] digital radio telemetry data is stored on the Motus network; some satellite and GPS data are on Movebank;[38] and some tracking products can be found on the Northeast and Mid-Atlantic Ocean Data Portals.

Appendix D: Discussion from the Developing Hypotheses and Identifying Study Methods Session

Panelists: Andy Webb (HiDef Aerial Surveying), Jocelyn Brown-Saracino (Department of Energy), and Andrew Farnsworth (Cornell Lab of Ornithology)

This plenary session was focused on practical aspects of assessing impacts to birds and bats from offshore wind energy development, including study methods and study design concepts to answer different types of questions. Topics addressed in Q&A periods—as well as additional detail provided by speakers on certain topics—have been summarized below.

- **European regulatory context.** The main legal instruments driving monitoring at offshore wind energy developments in Europe include the EU Birds Directive and the EU Habitats Directive. Implementation varies by country, but in general focuses on site protection. This contrasts with the U.S., where the regulatory process is primarily driven by protection of individual species. One commonality among EU countries is the application of the precautionary principle for consenting, or permitting, offshore projects. In the UK, expected maximum cumulative impacts across projects for some species are substantial enough to prevent further development in some areas.
- **Ancillary data collection in digital aerial surveys.** Digital aerial surveys record birds on the water and in the air, and these behaviors are distinguished in the data set. Altitude of flying birds is estimated by comparing the sizes of birds of known and unknown heights. This method has high uncertainty; more accurate altitude estimation methods are being explored.
- **Additional collision detection systems in development.** Besides those mentioned above, several other systems are in development that use sensor systems to detect collisions. The B-Finder technology is one example, although this system has not been tested offshore.
- **Pre-construction collision risk assessments in the U.S.** Unlike in the UK, where collision risk modeling is required, there is currently no formal collision risk modeling approach required for offshore wind energy developments in the U.S. BOEM risk assessments are based on an exposure analysis, which focuses on the likelihood of presence and high-risk behaviors.
- **Collision deterrence technologies.** Some deterrent concepts have been developed or are in development for land-based wind.[39] Technologies such as IdentiFlight have also been used to detect target species and trigger shutdowns at terrestrial wind facilities. Understanding risk is the first step to determine the need for deterrence or curtailment and to inform implementation.

- **Inference approaches.** Bayesian approaches represent an alternative framework to the traditional frequentist focus on binary hypothesis testing. Bayesian approaches are particularly well suited to some types of research questions, as they provide an estimated probability and uncertainty around that probability rather than a frequentist acceptance/rejection of the null hypothesis. This framework also allows for the incorporation of prior knowledge.
- **Putting impact studies in context.** It is important to recognize the positive effects of renewable energy on wildlife through climate change mitigation, while doing our best to minimize and mitigate direct impacts to wildlife from offshore wind development.

Appendix E: Generating Research Questions and Hypotheses

Workshop attendees participated in group discussions at the end of the first workshop day to expand on initial concepts, answer each other's questions, and begin refining research questions for breakout group discussions on the second day of the meeting. Several themes arose during these initial discussions, which are identified below; bullets may combine and summarize the views of multiple workshop participants as expressed during these conversations, and do not necessarily reflect the opinions of the majority of attendees.

Theme 1: Value of Asking Different Types of Questions

- There are a variety of reasons for asking different study questions, all of which may be valid. For example, some questions may focus on informing mitigation options, particularly compensatory or offset mitigation. Other questions may be driven by legislative requirements to maintain populations and make sure that species covered under the ESA are protected.
- Projects will be operational for 20–30 years, so we should think both short and long term. In the short term, we need to consider the value of additional information to influence activity or management. Are siting, design, and operations influenced by the answer to the question? We should think in terms of informing adaptive management. Longer term, building time series data and developing a better understanding of potentially impacted populations may have future benefits, even if the management value is not immediately evident. For example, understanding species during all parts of their annual cycle may be key in understanding whether offshore wind-related effects have population-level impacts. It may be beneficial to consider monitoring at breeding colonies or other key locations rather than solely at wind development sites.
- Knowing the footprints of planned developments (e.g., BOEM lease areas) provides an opportunity to ask questions related to understanding cumulative effects, including species-level risk, relative abundance of habitats, and full cycle population-level impacts.
- The priority for developers is to understand whether we are doing immediate harm, followed by longer-term questions about the environment and indirect impacts. Increased certainty in study priorities and methodologies will help assure all parties that offshore wind farm activity is not causing adverse impacts above what is acceptable, and if compensatory mitigation is required to correct for such an impact, developers will know how to achieve this.

Theme 2: Prioritizing Species and What Makes a Good Candidate Species to Study Impacts

- The U.S. regulatory process ensures a focus on endangered species, but they are often difficult to study. We should be focused on more than just federally listed species and use existing knowledge from Europe to identify species that are likely to exhibit the greatest impacts. Species that are sensitive to impacts may be different from species that are regulatory priorities, but substantive impacts can lead to future regulatory problems. There have been Europe-wide efforts to rank species in terms of sensitivity to offshore wind (Garthe and Hüppop 2004, Furness et al. 2013); such an exercise was also carried out for east coast of the U.S. (Willmott et al. 2013). Exercises like these can help inform priorities.
- As we know relatively little about migratory land birds in the offshore environment, they may be a priority—particularly those that are already of conservation concern. For example, red knots are a species of regulatory interest and there are data gaps regarding their behavior offshore.
- We should consider a focus on species or populations for which we have a high level of baseline information on population dynamics and demography, such as some colony-nesting species, to help inform our understanding of population-level impacts. This will require international coordination for some species.
    - Terns breed in the U.S. and there are often substantial existing colony monitoring efforts to build from. Additional data would need to be collected for some demographic parameters, but enhanced monitoring at colonies and staging areas could help inform parameterization of models to help understand the context for potential impacts from offshore wind development. Existing assessments (e.g. BOEM 2019b) should be used to help determine focus areas for future research.
    - We have a substantial knowledge base for northern gannets from studies at the Canadian breeding colonies, and there is a push for regulatory agencies to focus on pre-listed species (i.e., save species before issues arise). European studies suggest that risk of effects to this species may be high.
    - We could put together a matrix of species, feasibility, existing data collection efforts, expected impacts, etc. to help identify priority species for research. This could, in part, build from previous efforts to identify species most vulnerable to offshore wind impacts (e.g., Garthe and Hüppop 2004, Desholm 2009, Willmott et al. 2013, Furness et al. 2013)
- We could take a tiered approach, whereby we continue to focus on high-priority endangered species as the first tier, and the second tier focuses on more common species with a great deal of information that we can use to fill in gaps and develop models to help drive the direction of research for endangered species. Research priorities could be different for rare species and common species.

Theme 3: Utility of Surrogate Species

In many cases there is no alternative but to use a surrogate species to help understand a rare species' movements, behaviors, or expected effects. There are a range of considerations for use and suitability of potential surrogates, including the following:

- Differences between species such as flight behavior, buoyancy, and small structural and morphological differences may lead to differences in effects of research (such as tag effects) as well as effects of development. Before choosing a surrogate, we must understand the species' ecological niche and identify what level of aggregation among species is justified.
- The choice of a surrogate may depend not only on species of interest, but also impact of interest.
- Evidence for the effectiveness of surrogate species is lacking in the scientific literature (Murphy et al. 2011). Where possible, we should empirically assess whether a surrogate is a good stand-in by studying the species of interest and surrogate simultaneously.

Theme 4: Using Information from Other Industries

- Oil and gas structures have been in the marine environment for 40+ years and can provide insight into how these structures modify the environment, particularly around impacts from lighting (including studies by Memorial University and the USGS), end of life of structures and decommissioning, and artificial reef effects.
- We have a chance to learn from predecessors in other industries, particularly the terrestrial wind industry. Existing research programs can help provide a roadmap for the questions we might ask when approaching pelagic systems.

Theme 5: Information Sharing and Data Standardization

- Data transparency and dissemination of results are key so that we can compile data from multiple sites and examine impacts at a regional scale. Data transparency (including raw data, not just reports) is important to ensure that data from older projects are available for future analyses.
- BOEM has made a good start for data standardization, although existing guidelines could be stronger and clearer (See section 9: Next Steps). SeaScribe[40] is an example of a data standardization effort funded by BOEM.

Theme 6: Dealing with Uncertainty

- During permitting processes, regulators and developers must rely on existing information and make decisions in the face of uncertainty. Thus, we want to ensure research can reduce uncertainty and influence adaptive management.
- One aspect of uncertainty relates to teasing apart impacts from different stressors. Baseline and pre-construction research are required to understand use of the marine environment prior to development. Teasing apart impacts to animals throughout their annual cycle from different sources is a real challenge.

- We can reduce uncertainty by improving our understanding of populations more generally, including developing a stronger baseline knowledge of natural population fluctuations.

Theme 7: Strategic Planning and Analysis

- It would be beneficial to differentiate between project-level and regional-level questions.
- We should not overstate the value of monitoring population abundance, as detecting even gross changes in population size can be challenging (MacLean et al. 2013). We should think critically about the factors driving change and try to identify population or ecosystem parameters that are more sensitive while still being informative.
- It may be beneficial to think about different statistical and analytical frameworks that could be used for testing hypotheses. In particular, a Bayesian framework may be a good approach, as it provides an estimated probability and uncertainty around that probability rather than a frequentist acceptance/rejection of the null hypothesis. This framework also allows for the incorporation of prior knowledge.
- With highly migratory species that cross multiple jurisdictions, effects may be partitioned across the annual cycle, challenging our ability to tie impacts to wind or other phenomena. We need a better understanding of prey base, as well as the factors that may impact birds in wintering and staging areas and how those factors in turn might impact breeding success and survival.
- We need to think strategically: first, develop a plan for examining different hypothesized effects and gathering information on populations and ecosystems; second, implement individual studies; and third, use those results to inform decision-making and next steps.
- We should be using the mitigation hierarchy and focus first on developing knowledge to help avoid or minimize impacts before focusing too heavily on compensatory mitigation.

Appendix F. 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).
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.
Automated radio telemetry	Digitally coded radio tracking technology used in the Motus Wildlife Tracking System (brand names include “nanotags” and “lifetags”).
Avoidance	Any action taken by an individual when in proximity to an operational wind farm to prevent collision. Avoidance may occur at the scale of the wind farm (macro-avoidance), at the scale of the turbine (meso-avoidance), or at the scale of the turbine blade (micro-avoidance).
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 nonlinear relationships, incorporation of some types of environmental covariates, and a more informative assessment of effect size than BACI designs.
Baseline	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).
Boat-based survey	Systematic data collection (such as species abundance and distribution) from a moving vessel.
Community	A naturally occurring group of species interacting and occupying a habitat.
Cumulative Impacts	The effect of an impact on the environment, adding to, or interacting with, other impacts, on a similar temporal and/or spatial scale.
Density	The number of a specified organism per unit area.
Developer	Private sector entity involved in the development, construction, and/or operations of offshore wind farms.
Displacement	When animals adjust their habitat use, such as foraging or breeding, due to a new feature or disturbance, causing effective habitat loss.
Disturbance	Disruption of existing conditions for an organism or its habitat; generally, not directly lethal, but can affect wildlife in a variety of often negative ways.
Ecosystem	A biological community of plants and wildlife and their physical environment.
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.
Exposure	The extent of overlap in space and time between animals' distribution or abundance and offshore wind energy development.
eDNA	DNA released by organisms into the environment which can be monitored using molecular methods to detect species presence over a short temporal scale.
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.
Geolocator	A small archival tracking device that is attached to an animal to record ambient light levels in their vicinity which provides an approximate location. Data must be physically downloaded from the device (e.g., the device must be recovered). Generally used to map migration routes and identify important habitat use areas; location accuracy limitations can be substantial, but vary by location, species, tag attachment technique, and other factors.
LiDAR	Light Detection and Ranging is a remote sensing method typically used from a plane which uses light in the form of a pulsed laser to measure distance and, when combined with other equipment, to generate accurate three-dimensional spatial information.
Marine radar	Electronic instruments used for navigation and collision avoidance by ships at sea. Marine radars are X-band or S-band

	radars that use a rotating antenna to emit microwaves along the water's surface; microwaves reflect off nearby objects and generate an image of the ship's surroundings. Marine radars can also be operated vertically and can be used to detect birds and bats flying through the atmosphere. The detectable size of flying animals depends in part on the wavelength emitted by the radar, as well as the amount of interference presented by weather and other objects in the vicinity.
Nacelle	The structure that sits atop the tower of a wind turbine and houses key components, including the gear box and generator.
Nanotag	Small (0.2–3 g) digitally coded VHF radio transmitter that is attached to an animal to automatically record their presence as they pass within range of receiver antennas.
NEXRAD	Next Generation Radar, also known as WSR-88D weather surveillance radar. A network of these S-band Doppler weather radars is operated across the U.S. by the National Weather Service. They are designed to detect precipitation in the atmosphere by transmitting radio waves (wavelengths ~ 3 -10 cm) and receiving back the electromagnetic energy scattered by precipitation particles. Weather surveillance radars also regularly detect "bioscatter," or reflectivity of the electromagnetic energy caused by biological entities in the atmosphere, such as birds, bats, and insects. With distance from the radar station, the average height of the volume of air sampled by the radar beam increases in altitude and the power of the beam weakens, so it can be difficult to detect low-altitude and low-density objects with increasing range from a radar unit.
Power analysis	Analytical method allowing researchers to determine 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; productivity for upper trophic levels, such as seabirds, refers to recruitment of new individuals into the population via reproduction.
Radar	see "NEXRAD" and "Marine radar," above.
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.
Stressors	Physical, chemical, or biological factors that impact the health and productivity of a species or ecosystem.

Take	Under the Endangered Species Act (ESA), “take” of an endangered species means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Through regulations, the term “harm” is further defined to include direct harm to animals as well as significant habitat modification or degradation that leads to impairment of breeding, feeding, sheltering, or other behaviors.
Telemetry	The measurement of location data at a remote source and transmission of data (e.g., radio, satellite) to a monitoring station. Used to track animal movements.
TRL	Technology Readiness Level. Measurement system used by the Department of Energy to assess the maturity level of developing technologies.

Endnotes

1 Environmental Technical Working Group; www.nyetwg.com

2 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

3 Bird and Bat Scientific Research Framework Workshop: www.nyetwg.com/bird-bat-research-framework

4 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

5 Northeast Ocean Data Portal; www.northeastoceandata.org/, Mid-Atlantic Ocean Data Portal; https://portal.midatlanticocean.org/

6 Motus Wildlife Tracking System; https://motus.org/

7 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

8 But see more recent findings from a GPS tracking study of lesser black-backed gulls that suggest meso-scale avoidance of wind farm interior (Vanermen et al. 2020).

9 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

10 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

11 Biodiversity Research Institute Wildlife and Renewable Energy: Offshore Studies, Mid-Atlantic Baseline Studies; www.briloon.org/mabs

12 BOEM And MassCEC Release Marine Wildlife Survey Results To Guide Offshore Wind Development; www.boem.gov/newsroom/press-releases/boem-and-masscec-release-marine-wildlife-survey-results-guide-offshore-wind

13 Normandeau Associates Remote Marine and Onshore Technology: NYSERDA; https://remote.normandeau.com/nys_overview.php

14 Normandeau Associates Remote Marine and Onshore Technology: BOEM; https://remote.normandeau.com/boem_overview.php

15 Atlantic Marine Assessment Program for Protected Species; www.fisheries.noaa.gov/new-england-mid-atlantic/population-assessments/atlantic-marine-assessment-program-protected

16 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

17 Guidance from the Bird Banding Laboratory suggests that auxiliary markers, such as transmitters, that are affixed to birds should generally represent no more than 3% of their body weight, in order to reduce the risk of tag effects (e.g., negative effects to their behavior, survival, or reproduction). Common terns for example generally weigh 110–141 g, so are able to carry automated radio transmitters, as well as the very smallest satellite and GPS transmitters.

18 ARGOS; www.argos-system.org

19 Analog VHF tags are an additional option for small-bodied animals, although the requirement for manual detection has limitations in the offshore environment. GPS data loggers and geolocator data loggers are also lightweight options in situations where the animal can be recaptured for tag recovery.

20 Bureau of Ocean Energy Management: Renewable Energy; https://www.boem.gov/renewable-energy

21 Tethys Knowledge Base; http://tethys.pnnl.gov/knowledge-base-marine-energy

22 Motus Wildlife Tracking System: Publications; http://motus.org/data/publications

23 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

24 eBird; https://ebird.org/home

25 BirdCast; https://birdcast.info/

26 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

27 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

28 The R-INLA Project; www.r-inla.org/, INLABRU; https://sites.google.com/inlabru.org/inlabru

29 For other studies of barrier effects, see Masden et al. (2009, 2010)

30 Presentation is available on the project website at: www.nyetwg.com/bird-bat-research-framework

31 Biodiversity Research Institute Data Management: Seascribe; www.briloon.org/seascribe

32 BatAMP: Bat Acoustic Monitoring Portal; https://batamp.databasin.org/

33 Transparent modeling of collision risk for three federally-listed bird species to offshore wind development; www.boem.gov/sites/default/files/documents/environment/environmental-studies/Transparent%20modeling%20of%20collision%20risk%20for%20three%20federally-listed%20bird%20species%20to%20offshore%20wind%20development.pdf

34 Environmental Technical Working Group: Regional Wildlife Science Entity; www.nyetwg.com/regional-wildlife-science-entity

35 USGS: State Wildlife Action Plans (SWAP); https://www1.usgs.gov/csas/swap/

36 IdentiFlight; www.identiflight.com/

37 BatAMP: Bat Acoustic Monitoring Portal; https://batamp.databasin.org/

38 Motus Data Tracking System; motus.org, and Moveback for Animal Tracking Data; www.movebank.org

39 Deterrent technologies have shown some promise for reducing bat fatalities in some species at terrestrial facilities, although there is little evidence of effectiveness for Eastern red bats (the most commonly found species offshore) and at least one study actually found an increase in Eastern red bat mortality in relation to use of an ultrasonic acoustic deterrent (Schirmacher 2020).

40 Biodiversity Research Institute Data Management: Seascribe; www.briloon.org/seascribe

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

New York State Energy Research and Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov