Bats Workgroup Report

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

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Additional Information

This report is one outcome from a broader effort to review the state of knowledge regarding offshore wind energy development's effects on wildlife and identify short-term research priorities to improve our understanding of cumulative biological impacts as the offshore wind industry develops in the eastern United States. This effort, titled *State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts*, included a week of plenary presentation sessions and contributed talks in November 2020, as well as the formation of six other workgroups similar to bats workgroup that met over the winter of 2020-2021. This report, and those from the six other workgroups, are available on the workshop website at http://www.nyetwg.com/2020-workgroups.

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Background

The 2020 State of the Science Workshop, hosted by the New York State Energy Research and Development Authority (NYSERDA), was held virtually from November 16-20, 2020. This workshop brought together over 430 stakeholders engaged with environmental and wildlife research relevant to offshore wind energy (OSW) development. The aim of the workshop was to assess the state of the knowledge regarding OSW development's potential cumulative impacts on wildlife populations and ecosystems. **For this effort, cumulative impacts were defined as interacting or compounding effects across spatiotemporal scales, caused by anthropogenic activities relating to the development and operation of multiple offshore wind energy facilities, that collectively affect wildlife populations or ecosystems** (see call-out box for definitions of "effects" and "impacts").[1] Attendees included a wide range of stakeholders from offshore industry, government agencies, non-profit organizations, and academia. More information can be found at http://nyetwg.com/2020-workshop.

Following the plenary sessions in November, workshop attendees formed seven taxon-specific workgroups focusing on benthos, fishes and mobile invertebrates, birds, bats, marine mammals, sea turtles, and environmental change. Workgroups, under the guidance of lead technical experts, met virtually in late 2020 and early 2021 to identify scientific research, monitoring, and coordination needs to improve our understanding of cumulative impacts from OSW development. **The goal for each group was to identify a list of studies that could be implemented in the next five years to position the stakeholder community to better understand potential cumulative biological impacts as the OSW industry develops in the U.S.**

The intended audience for this report encompasses a range of stakeholders including researchers, state and federal agencies, OSW developers, regional science entities, and other potential funding entities who could potentially target these priorities for future funding. The priorities identified below should not be interpreted as research that must occur prior to any development activity; rather, these priorities are intended to further inform environmentally responsible development and minimize cumulative impacts over the long term. Many of these research needs are specifically directed at understanding and measuring effects as the industry progresses.

Workgroup members represented a wide range of perspectives from offshore industry, government agencies, non-profit organizations, and academia, and provided key input based on their respective specialties. Workgroup meetings included presentations as well as small and large group discussions to identify and prioritize key topics of interest. Workgroup members also provided input on the relative priority of different topics via live polls during meetings and/or online surveys between meetings. All workgroup documents were shared with workgroup members via a document collaboration platform (e.g., Google Drive, Microsoft Teams), and workgroup members had multiple opportunities over the course of several

> **Defining Impacts vs. Effects** (from Hawkins et al. 2020)
>
> ***Effect:*** a change caused by an exposure to an anthropogenic activity that is a departure from a prior state, condition, or situation, which is called the "baseline" condition.
>
> ***Impact:*** a biologically significant effect that reflects a change whose direction, magnitude and/or duration is sufficient to have consequences for the fitness of individuals or populations.

[1] This effort was focused on better understanding effects specifically from offshore wind energy development. This was not intended to imply that offshore wind is causing greater impacts than other stressors. Cumulative impact estimates for offshore wind energy development will be useful in broader cumulative impact frameworks that include impacts from multiple types of anthropogenic activities.

months to provide written input on earlier drafts of this report. The report indicates a general consensus among workgroup members, unless otherwise noted; where there was stated disagreement among workgroup members on a recommendation, this disagreement is noted in the text. Despite the substantial input and influence of workgroup members on the workgroup reports, final report contents were determined by the technical leads, in some cases with support from an additional small subgroup of experts within the group.

The bat workgroup's technical lead was Cris Hein (Senior Project Leader, National Renewable Energy Laboratory), with technical and logistical support from Kate Williams, Edward Jenkins, and Julia Gulka (Biodiversity Research Institute) and Ashley Arayas and others (Cadmus Group). The workgroup consisted of 37 participants (Appendix A), who met virtually twice in the winter and spring of 2020-2021. More information about the workgroups can be found at http://www.nyetwg.com/2020-workgroups.

Introduction

The concern regarding potential bat collisions and OSW is derived from our understanding of the interactions with bats and the land-based wind industry. Across the United States and Canada, estimates of collision fatalities are in the hundreds of thousands per year with tree-roosting species (e.g., eastern red bats [*Lasiurus borealis*], hoary bats [*L. cinereus],* and silver-haired bats [*Lasionycteris noctivagans*]) comprising approximately 78% of bat mortality at land-based wind energy facilities (Arnett and Baerwald 2013). Mortality patterns indicate a peak during late summer and early fall during warmer temperatures and lower wind speeds (Arnett and Baerwald 2013, American Wind Wildlife Institute 2020). One key factor potentially explaining the observed patterns of mortality is the apparent attraction to wind turbines or wind energy facilities (Kunz et al. 2007, Cryan and Barclay 2009, Horn et al. 2008, Cryan et al. 2014). Given this level of mortality and projected terrestrial build out (U.S. Department of Energy 2015), the magnitude of the effect may result in population-level declines and increased extinction risk for at least one of these species, the hoary bat (Frick et al. 2017, Electric Power Research Institute 2020).

Currently, there is a paucity of data regarding offshore movement patterns of bats. However, available data indicates that while levels of activity are generally lower offshore compared to onshore, the timing and conditions of offshore bat observations resemble patterns of activity recorded onshore. If behavioral and physiological drivers that attract bats to land-based wind turbines also exist, then individual collision risk at offshore wind energy facilities may be similar. However, OSW facilities also differ from land-based facilities in several ways, including the size of turbines, spacing between turbines, and likely use of Aircraft Detection Lighting Systems (ADLS), which are expected to greatly reduce active lighting on turbine towers. To understand potential exposure, additional baseline surveys are warranted to build on existing scientific knowledge, including:

1) At least seven species use the U.S. Atlantic offshore environment, including big brown bats (*Eptesicus fuscus*), eastern red bats, hoary bats, *Myotis* spp., silver-haired bats, and tri-colored bats (*Perimyotis subflavus*). The most commonly observed species offshore is the eastern red bat (40-64% of detections; Hatch et al. 2013, Sjollema et al. 2014, Stantec Consulting Services Inc. 2016). The other migratory tree bats also appear to be widespread at offshore sites, though they are much less common. *Myotis* spp. are less consistently detected across offshore

locations, but collectively represent the most common species group in some areas (Stantec Consulting Services Inc. 2016).

2) The flight height for most observations is near the ocean surface, though many observation methods are likely biased towards lower elevations, and bats have been observed flying 200+ m above sea level (Hatch et al. 2013).
3) In the eastern U.S., bats (n=35) were detected between 5.3 and 129.6 km (mean 60.3 km) from shore on 7 of 52 nights of monitoring aboard a ship (Stantec Consulting Services Inc. 2016). Hatch et al. (2013), using digital aerial surveys and ship-based monitoring, documented bats between 16.9 and 41.9 km from shore in the mid-Atlantic U.S. Those authors also reviewed historic observations of bats offshore of eastern North America, including anecdotal records of bat presence up to 1949.9 km offshore with an average distance from shore of 103.6 km.
4) Broad-scale patterns of offshore bat activity appear similar in Europe, with most offshore detections of migratory species during migration periods, with such detections occuring at substantial distances from shore (Boshamer and Bekker 2008, Lagerveld et al. 2015; Lagerveld et al. 2020).
5) Anecdotally, bats have been observed on ships, small islands, and offshore structures, including roosting on wind turbines (Ahlén et al. 2009). These structures may provide stopover sites for migrating bats (Cryan and Brown 2007).
6) In the eastern U.S. and Great Lakes, most offshore bat activity (86%) occurs between 15 July–15 October (Stantec Consulting Services Inc. 2016). Similar to coastal terrestrial locations (Smith and McWilliams 2016, Dowling 2017), more offshore bat activity occurs during warmer temperatures and lower wind speeds. A combination of Julian date, wind speed, and temperature explains 64–89% of the variation in bat activity in the offshore environment, depending on the U.S. geographic region of interest (Stantec Consulting Services Inc. 2016).
7) There are little available data on bat activity around operational offshore wind turbines. However, Brabant et al. (2018) found that bat acoustic activity at nacelle height (97 m above sea level) was only about 10% of the acoustic activity at turbine platform height (17 m above sea level) at several offshore wind turbines in the Belgian part of the North Sea.

Risk depends on a combination of the three elements of exposure, hazard, and vulnerability (Fig. 1; Crichton 1999). Based on our current understanding of bats and land-based wind energy development, data indicates the spinning blades are the hazard, migratory tree-bats appear to be the most vulnerable to collisions, and periods of relatively low wind speeds during approximately July through October

Fig 1. The “risk triangle,” from Crichton (1999).

represent the greatest risk of exposure (i.e., when the most bats may be present near turbines to be affected by the hazard). The exposure level may be higher for some species given their apparent attraction to wind turbines/wind energy facilities. For OSW, the hazard and vulnerability are presumably the same as terrestrial facilities, but the exposure may not be equivalent, which would change the total risk (e.g., the area included in the "risk triangle"). Limited data indicate bats are offshore during the same times and conditions, but available information suggests lower activity levels in the offshore environment relative to many terrestrial systems, and it is possible that behavioral responses to turbines may also differ.

Given the lack of information on bats offshore and the potential risk of collision with OSW turbines, it is necessary to answer several questions regarding potential exposure. Ideally, assessing the potential cumulative impacts of offshore wind energy would involve collecting data regarding the proportion of bats which occur offshore, the level of collision risk, and, if necessary, the level of mitigation required to sustain viable populations. However, we currently lack effective methodologies to assess population sizes for many bat species, to determine the relative proportion of a population occurring in different geographic areas, or to estimate sustainable levels of wind industry-related collision mortality for many bat species; effective methodologies to address these questions are not likely to become available in the next 3–5 years. Instead, the "next best" approach is to assess relative bat exposure to wind energy and collision risk in the offshore environment compared to onshore locations, and to understand how relative exposure and risk differ across time and space (Fig. 2). A variety of technologies may be necessary to understand bat activity and behavior patterns at various scales (Hein 2017, Molis et al. 2019). Below are several areas of research that may improve our understanding of the potential effect of offshore wind energy on bats, organized hierarchically (Fig. 3).

It is important to establish a baseline level of pre-construction activity to which post-construction activity and mortality can be compared. The next several years represent the only opportunity to collect these data, and this is an opportunity for the offshore wind energy and environmental community to be proactive in collecting data. **However, given the possibility of attraction to offshore turbines, pre-construction data may not fully inform our understanding of risk, and therefore post-construction monitoring is the primary research objective.** If post-construction mortality monitoring indicates generally low risk, then there is a potential "exit strategy" (Ruiz-Miranda et al. 2020), indicating mitigation measures are unnecessary (Fig. 3). If mortality risk is high, then additional research may be warranted to better understand the drivers of risk and how best to mitigate the impact.

In the text below, priorities are split into three categories:

- Short-term research needs
- Other short-term needs (i.e., data standardization, technology integration, etc.)
- Longer-term needs that cannot be addressed within the next five years, but may become priorities in future based on the outcomes of initial short-term research.

The relative priority of each short-term need is identified below. Given that the outcomes of initial studies may strongly affect the choice of future studies (Fig. 3), the workgroup chose to list these needs in thematic/chronological order rather than in order of priority.

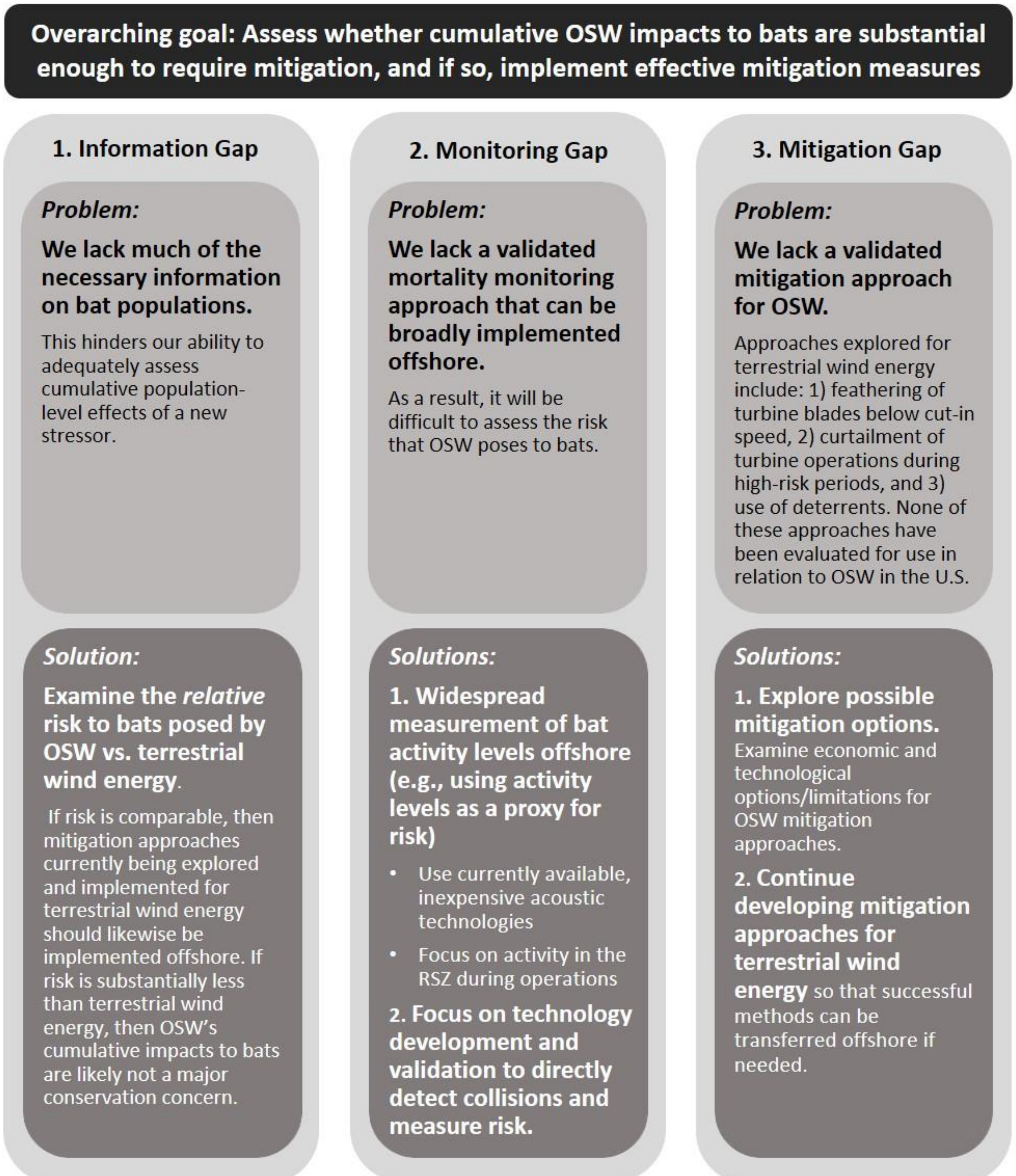

Fig 2. Key data gaps and potential solutions for addressing the overarching goal of understanding and, if necessary, minimizing the effects of offshore wind (OSW) development on bats in the eastern U.S. RSZ=rotor-swept zone.

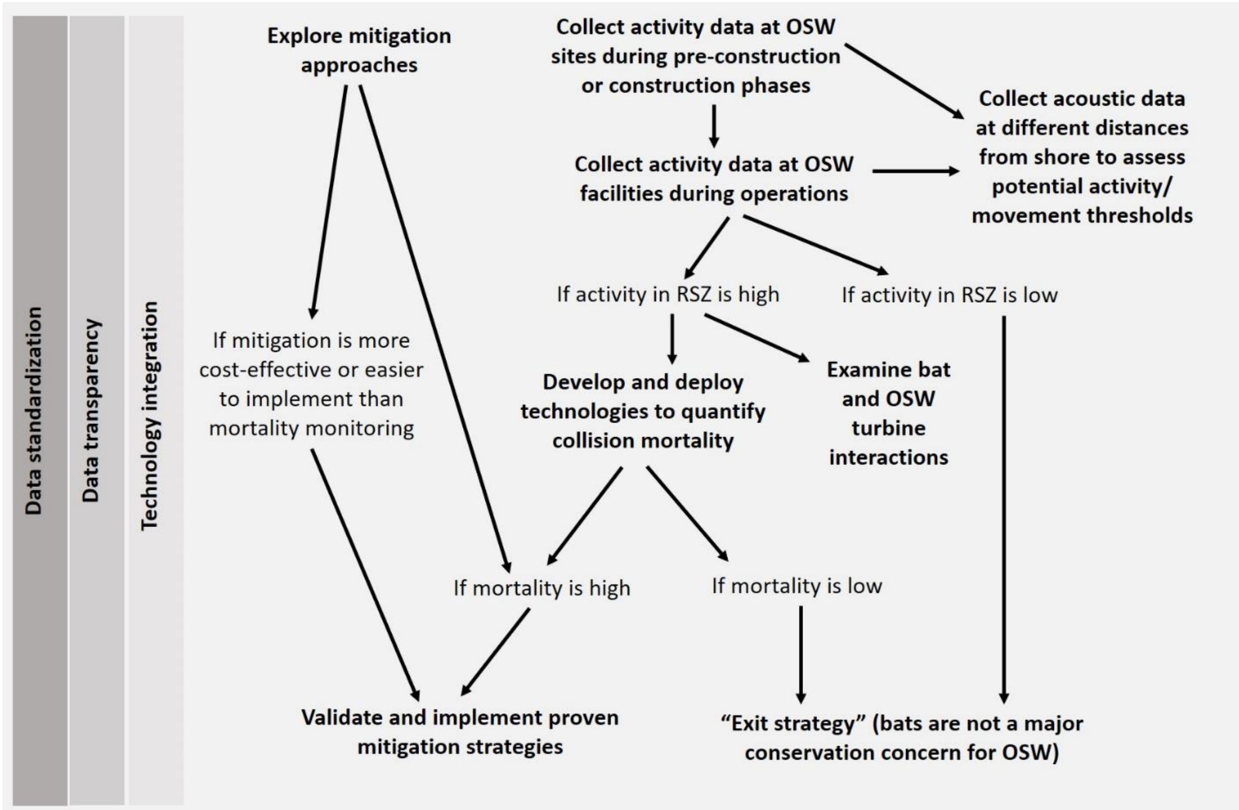

Fig 3. Proposed order of operations to improve our understanding of the cumulative biological impacts of offshore wind (OSW) development to bats in the eastern U.S. Outcomes of initial studies will inform future steps and should serve to refocus efforts as needed. Each proposed step is discussed in further detail below. RSZ= Rotor-swept zone.

Short-term Research Needs

Bat activity and movement patterns

Goal: Understand patterns of bat activity, movement, and habitat use in the offshore environment, to assess the degree of likely interactions with offshore wind energy facilities. This is the first and relatively easiest research area to address, primarily via the use of passive acoustics.

- **Objective 1: Collect baseline data at the proposed development site during the pre-construction or construction phases of the project.** These data can be used to assess the timing and activity patterns in the area and to assess potential risk. Baseline data can be compared to post-construction data to determine whether changes in activity exist. Baseline data can also be compared to post-construction mortality monitoring data (see "Developing and deploying technologies to quantify collision mortality" priority below), to determine whether a relationship exists and if baseline data can be used to predict risk. No consistent relationship between pre-construction activity and post-construction mortality exists at land-based wind energy facilities (Solick et al. 2020), but it may be possible to improve these analyses by focusing pre-construction risk assessments on periods for which turbines would be operational (e.g., wind speeds above the manufacturer's cut-in speed). Coordination and standardization of baseline data collection efforts are needed to ensure that data are collected in such a way as to best inform our understanding (see also "Other Short-term Priorities," below). Standardized methods should include the collection of local weather data within the proposed facility footprint to ensure the timing of bat activity can be examined in relation to meteorological factors.

Priority: **Medium.** Pre-construction data should be collected for the first large-scale OSW projects in the eastern U.S. to determine their relative utility. Pre-construction activity patterns are unlikely to be used to inform the siting of offshore wind energy projects, but these data may be useful for informing the degree of focused monitoring that may be needed at each site, and will be useful for improving our general understanding of bat biology in the offshore environment.

- **Objective 2: Collect activity data at the wind energy facility during the operational phase of the project.** Post-construction activity data can be compared to baseline data to see if activity levels change with the presence of wind turbines. Post-construction data may also provide a better predictor of risk, because detectors can be located on the nacelles of wind turbines to sample the airspace within the rotor-swept zone. Coordination and standardization of data collection efforts are needed to ensure that data are collected in such a way as to best inform our understanding (see "Data standardization," below).

  Priority: **High.** If attraction occurs once turbines are built, then data from the operational phase are necessary to understand risk. This research is the most essential from an applied conservation standpoint to assess what effects are occurring and when.

- **Objective 3: Collect acoustic data to assess potential activity and movement thresholds from shore.** These data may assist with siting and other mitigation decisions (e.g., to focus on areas with lower bat activity and risk). This requires a roughly linear or grid-based study design with acoustic detectors at varying distances from shore, possibly including detectors sited independently of any specific OSW project site (e.g., on vessels, buoys, or other platforms). Data could also be collected along the coast to determine whether activity varies with latitude.

  Priority: **Low.** This is not an immediate priority, as it will require substantial data to answer the question and is probably not achievable in the next five years. However, if activity in the rotor-swept zone is determined to be high for at least some OSW locations, it would be beneficial to assess whether there are environmental gradients that may influence risk.

Potential methods: Acoustic detectors may be the most cost-effective technology to address this research topic because they are relatively inexpensive, easy to deploy, and are able to remotely record data for extended periods (though there are microphone reliability and data storage concerns that must be considered for long-term offshore deployments). However, the placement of acoustic detectors during the pre-construction phase (i.e., closer to the surface of the water and not in the rotor-swept zone) will likely bias data toward relatively low-flying bats and may miss species that are more often detected at higher altitudes. Acoustic studies should be conducted between sunset to sunrise from spring through fall, though study duration may vary based on latitude (e.g., locations farther south may require a longer study period) or as more data become available (e.g., data indicates spring and early summer activity is negligible and no longer necessary). Detector microphones should be positioned as high as possible such that they record activity within the rotor-swept zone. Data should be analyzed to species level when possible. Metrics used for interpretation of acoustic data should be carefully considered relative to the question being asked. The number of sampling stations depends on several factors, including the size and shape of the wind energy facility. Detectors should cover any variability within the project area, including the closest and farthest distances from shore. Bat activity data should be examined in relation to several factors, including spatial variation (e.g., distance from shore), temporal variation (e.g., time of year), local weather (e.g., wind speed), foraging conditions (e.g., insect abundance, if such data are available), and operational conditions (e.g., revolutions per minute). All data should be provided to existing databases such as the Bat Acoustic Monitoring Portal (BatAMP)[2] and the North American Bat Monitoring Program (NABat)[3] to help assess largescale spatio-temporal patterns. If a relationship between activity and mortality can be determined, either from pre-construction or post-construction acoustic data, it may provide a cost-effective approach to assessing collision risk for bats.

Collecting occurrence data over space and time is necessary to assess bat population trends. A broad-scale, long-term research objective relates to understanding the proportion of bats using the offshore environment. This is an important component to understanding the potential cumulative impacts of offshore wind energy on bats. This could be achieved by extending the NABat grid farther offshore and following their sampling protocol (the current grid extends roughly to the 3-mile offshore boundary of state-controlled waters in the eastern U.S.). An expansion into the Atlantic Outer Continental Shelf is currently in process (B. Straw pers. comm., April 2021). These data could be combined with results onshore, including at coastal sites, to assess patterns of activity and relative habitat use at inland, coastal, and offshore sites, and to estimate population-level trends (similar coastal-offshore comparisons are in progress in the Pacific and Virginia). Assessing the trend in bat activity offshore over time may provide insight on whether increasing deployment represents a population-level risk (i.e., bat occurrence offshore decreases over time).

Other technologies besides acoustics may also be useful to obtain information on individual movement patterns (e.g., radio telemetry or GPS tags). Increasing the offshore Motus network and number of tagged bats could provide new information on individual movements, and guidance for the use of Motus telemetry in relation to OSW is currently in development[4]. In addition, when capturing bats and attaching tags, hair and tissue data can be collected and used for additional isotope or genetic analyses.

Existing research: There are limited data available from offshore wind facilities in Europe, but existing studies do not suggest that bat activity (and thus potential risk) is higher in the rotor-swept zone than at platform height during the operational period (e.g., Brabant et al. 2020).

Developing and deploying technologies to quantify collision mortality

Goal: Quantify bat mortality at OSW facilities to determine whether mortality rates are high enough to be a regulatory or conservation concern.

***Priority:* High**. These data will help confirm whether collision risk is a concern for the offshore wind energy industry.

Potential methods: There is a paucity of data to determine population-level consequences for most bat species. An early step in assessing the effect of OSW on bats is to compare mortality to levels observed at terrestrial wind energy facilities (which we know are sufficient to cause population-level impacts to at

[2] BatAmp https://batamp.databasin.org
[3] NAbat www.nabatmonitoring.org
[4] Automated radio telemetry guidance www.briloon.org/renewable/automatedvhfguidance

least one species of migratory tree bat; Frick et al. 2017). While it may not be feasible in the short term (e.g., within the next five years) to fully assess whether fatality rates are high enough to be a regulatory or conservation concern, it is possible on this timeframe to further develop the necessary monitoring technologies and begin quantifying bat mortality at offshore wind energy facilities (see specific considerations below).

Quantifying mortality at OSW energy facilities will require an entirely different approach than at land-based wind energy facilities (see Weaver et al. 2020 for example methodology). It is likely that technologies will be required to detect actual collision events as opposed to searching for carcasses after the fact as is routinely used at land-based facilities. This requires 1) operational wind turbines and 2) the technology to quantify collision events. Currently, there are few operating offshore turbines to sample and existing technologies to quantify collisions are undergoing validation studies; further development is likely needed for detecting small-bodied animals such as bats. Multiple integrated technologies are necessary to accurately detect and confirm a collision event and identify the taxon (i.e., distinguish between birds and bats) or species (i.e., hoary bat vs. eastern red bat). These technologies may include a combination of strike detectors, thermal cameras to detect animals in the area around rotors or to detect falling carcasses, and acoustic detectors. Data analysis should examine mortality in relation to several factors, including spatial variation (e.g., distance from shore), temporal variation (e.g., time of year), local weather (e.g., wind speed), foraging conditions (e.g., insect abundance), and operational conditions (e.g., revolutions per minute). These technologies may also provide insight regarding bat interactions with wind turbines (see "Explore bat and offshore wind turbine Interactions" below).

Considerations for technology development and deployment include:

- A cost-benefit analysis of different technologies (and combinations of technologies) could be valuable. Integration of higher-cost and lower-cost technologies also would be useful to assess correlations in their results and potentially allow for higher-cost systems to be deployed in more limited fashion over the longer term.
- Technologies should be validated, and their biases identified, at land-based wind energy facilities prior to offshore deployment. The biases of traditional land-based fatality monitoring, such as searcher efficiency, are well articulated and accounted for in mortality estimation software (e.g., Generalized Mortality Estimator[5]), but relatively unknown for other collision monitoring technologies. Therefore, it will be critical to articulate and account for the biases associated with any technology used. Agreeing upon and adopting a data standardization protocol to be used by all researchers carrying out similar work would allow the identification of correction factors (see "Data standardization" below).
- Communicating the integration needs (e.g., placement, communication requirements, power requirements) with the wind industry is important (see "Technology integration" below). Whenever possible, monitoring plans should be integrated into turbine designs prior to construction.
- One benefit of using technologies to assess mortality is that they collect real-time information of collision events. Collision events should be related to spatial and environmental factors collected on-site when possible. Local weather data and operational data should be provided to researchers by OSW farm operators.
- Studies should be conducted from spring through fall. Study duration may vary based on latitude (e.g., locations farther south may require a longer study period) or as more data

[5] Generalized Mortality Estimator https://www.usgs.gov/software/genest-a-generalized-estimator-mortality

become available e.g., data indicates spring and early summer activity is negligible and no longer necessary).

- The appropriate sample size of turbines to be monitored may initially be based on guidance from land-based studies (e.g., all turbines sampled if under <10; if ≥10, then 10 turbines or 20% of the project, whichever is greater; Pennsylvania Game Commission 2013, U.S. Fish and Wildlife Service 2012).
- The need for collision monitoring technologies to inform estimates of collision risk has also been identified for birds in the offshore environment (e.g., Cook et al. 2021), and technology development would ideally consider monitoring needs for both taxa.

Other Short-term Priorities

There are several other immediate needs that will be important or even essential to adequately address the above research priorities, and should be integrated into efforts to address the above research priorities, as appropriate. These topics are listed below.

Data standardization

Goal: Standardizing data collection, analysis, and reporting is essential.

Priority: **High**

Potential methods: Some guidance is available based on land-based studies, but it may need to be adapted for data collected in the offshore environment. Lessons learned from terrestrial wind energy research should be applied consistently for OSW monitoring (e.g., standardized post-construction acoustic monitoring methods should include the collection of local weather data at nacelle height and turbine operational data to ensure the timing of bat activity can be correlated to meteorological factors and turbine energy production). In addition, there is a need to standardize terminology. For example, 'high-risk' and 'low-risk' remain undefined. Defining acceptable levels of risk will be important for decision makers to determine appropriate exit strategies or mitigation. If this need is not addressed elsewhere (e.g., via the release of OSW-focused guidance by state or federal agencies), it may be necessary to convene a group to develop recommended practices for monitoring and explore how to define acceptable levels of risk.

A need for methodological and data standardization and transparency was also noted in other State of the Science workgroups, including those focused on the benthos (Degraer et al. 2021), marine mammals (Southall et al. 2021), birds (Cook et al. 2021), bats (Hein et al. 2021), acoustic effects on fishes and aquatic invertebrates (Popper et al. 2021), and environmental stratification (Carpenter et al. 2021).

Data transparency

Goal: All data should be made publicly available in a timely manner so that it can be used to assess broad-scale questions and potential cumulative impacts.

Priority: **High.**

Potential methods: There are available databases for acoustic data (NABat and BatAMP) and for land-based mortality data (American Wind Wildlife Information Center [AWWIC])[6]. There are currently no public databases (that we are aware of) for imagery from thermal cameras or other monitoring approaches. NABat, in particular, is currently expanding their scope to the offshore environment such that their database can accept and house data collected at OSW farms. Findings from monitoring and research studies should be published in peer-reviewed reports and publications.

Technology integration

Goal: There is a need for providers of monitoring technologies to coordinate early and often with the turbine manufacturers and wind energy operators (Nielsen 2018, Nielsen et al. 2019). Guidance is needed on the constraints (e.g., placement options, remote communication, power) for technology installation.

***Priority:* High**

Potential methods: A workshop may provide a possible venue to connect relevant stakeholders (e.g., turbine manufacturers, technology providers, wind industry representatives, researchers, regulatory agencies) to discuss technology requirements and feasibility and to begin developing guidance.

Exploration of mitigation approaches

Goal: Understanding the cost-benefit ratio of implementing mitigation is a crucial first step in developing feasible strategies. There is a need to understand the financial and legal constraints of the wind energy industry as well as the conservation effectiveness of potential mitigation strategies.

***Priority:* High**

Potential methods: A workshop is warranted to discuss topics such as 1) the adoption of the American Wind Energy Association (now American Clean Power Association) 2015 best management practice of feathering blades below the manufacturer's cut-in speed to minimize mortality when energy is not being produced, 2) the criteria that trigger mitigation, 3) the strategies available or currently being validated, 4) the costs and logistics of implementation, and 5) how the offshore wind energy and wildlife community can support research underway at land-based wind energy facilities.

There was some discussion among workgroup members about when and how to address mitigation options for OSW. All workgroup members agreed that if monitoring indicated high risk to bats, mitigation should be required. However, several workgroup members advocated for immediate precautionary implementation of some mitigation measures in the offshore environment prior to data collection (such as feathering turbine blades up to the manufacturer's cut-in speed) and indicated that this topic of exploring mitigation options was their top priority.

[6] AWWIC https://awwi.org/resources/awwic-bat-technical-report/

Long-term Research Needs

While the primary goal for this workgroup was to identify a list of studies that could be implemented in the next five years to better understand potential cumulative biological impacts to bats, the group also identified several longer-term "conditional" priorities – e.g., topics that may become research priorities based on the outcomes of the initial shorter-term research defined above. These topics are listed below.

Explore bat and offshore wind turbine interactions

Goal: If bat activity levels increase with the presence of turbines and/or mortality is high, monitor bat interactions with wind turbines to assess whether attraction behaviors are similar to those observed at land-based wind energy facilities.

Potential methods: If the above studies suggest that offshore wind development presents a risk to bats (or certain species of bats), then understanding the behavioral and physiological drivers of these interactions will be important. Bats appear to be attracted to land-based wind energy facilities and wind turbines (Cryan and Barclay 2009, Cryan et al. 2014, Richardson et al. 2021), but questions remain regarding the drivers of this behavior. There are several hypotheses, some of which may also apply to offshore wind energy facilities and wind turbines. Understanding why bats interact with wind turbines may help in developing cost-effective mitigation strategies.

- A combination of thermal cameras and acoustic detectors positioned to record data within the rotor-swept zone can be a cost-effective approach to monitoring bat interactions with wind turbines (Cryan et al. 2014) and may already be deployed to quantify mortality (See "Developing and deploying technologies to quantify collision mortality" above). Both technologies provide real-time data, but thermal cameras' area of detection is greater relative to acoustic detectors (Hein 2017) and can record bats that are not echolocating, whereas acoustic detectors can help identify species-specific behaviors. Radio telemetry may also be useful to assess species-specific interactions in association with relevant covariates.
- When visiting wind turbines (e.g., for maintenance), scanning the interior for the presence of bats or guano can confirm whether bats are using turbines as roosting locations. Observations of bats roosting in offshore wind turbines has been observed in Europe (i.e., Ahlén et al. 2009).
- Studies should be conducted during the period of peak mortality to maximize observations (Hein 2017, Molis et al. 2019).

Validate and implement mitigation

Goal: If offshore wind presents a high risk to bats (or certain species of bats), then developing cost-effective approaches to mitigate effects will be necessary to address cumulative impacts. If bat mortality at offshore wind turbines is found to be high (e.g., comparable to onshore wind energy facilities), validate and implement proven mitigation strategies to reduce bat mortalities at wind turbines. For example, nacelle-mounted deterrents may not reach far enough to cover the full blade length for larger offshore turbines, necessitating consideration of blade-mounted systems or a combination of approaches.

Potential methods: A desired level of mortality reduction should be identified to sustain viable populations, and a mitigation strategy must be proven to reduce mortality below this desired level.

Existing options have been studied at land-based wind energy facilities, including curtailment and ultrasonic deterrents. However, its likely these will need to be modified to be successful offshore.

- Relate post-construction acoustic, video, and mortality data to weather and operational parameters to develop smart curtailment algorithms.
- Support validation studies at land-based wind energy facilities and efforts to modify strategies for the offshore environment.
- Experimental designs, such as completely randomized or randomized block designs, can be used to compare treatment to control conditions (Sinclair and DeGeorge 2016). Conduct a power analysis prior to any experimental study to determine the appropriate sample size. Conduct studies during the period of peak mortality to maximize sample size.
- Understanding the movement patterns of bats (e.g., determining whether there is a distance from shore threshold below which bat activity is negligible) may provide a unique option for offshore wind. These data will be collected in the short term (above) and can be used to plan future wind energy development.

Conclusions

We are currently unsure of the level of risk posed to bats by OSW development. Given the unintentionally high mortality caused by terrestrial wind turbines, and evidence of widespread bat presence offshore (though generally at much lower activity levels than terrestrial locations), it seems appropriate to also assess potential risk at offshore facilities. Monitoring bat activity rates in the post-construction phase is possible with current technology, and given the apparent attraction of bats to turbines in the terrestrial environment, this monitoring during the operational phase should be a priority. Quantifying mortality, though also a priority, will require additional technological development as well as integration of monitoring technologies into turbine infrastructure. Data standardization and transparency will be essential for pooling sufficient data to answer key questions.

Given the population-level risk posed to certain species of bats from terrestrial wind energy development, there were varying opinions among workgroup members regarding the timeline on which mitigation (e.g., adopting the best management practice of feathering up to the manufacturer’s cut-in speed) should be implemented. Some workgroup members felt that mitigation should be implemented in the offshore environment on a precautionary basis while data on risk is collected. At minimum, in the short term, we recommend conducting a cost-benefit exploration of available mitigation approaches and constraints.

Literature Cited

Ahlén I., H.J. Baagøe., and L. Bach. 2009. Behavior of Scandinavian bats during migration and foraging at sea. Journal of Mammalogy 90(6):1318-1323.

American Wind Wildlife Institute. 2020. AWWI technical report: 2nd edition: Summary of bat fatality monitoring data contained in AWWIC. Washington, DC. Available at: https://awwi.org/wp-content/uploads/2020/11/Bat-Technical-Report-Result-Summary-11_24_20.pdf

Arnett, E.B, and E. Baerwald. 2013. Impacts of wind energy development on bats: Implications for conservation. In: R. Adams and S. Pedersen (eds). Bat evolution, ecology, and conservation, Springer, New York. 435-456.

Boshamer, J.P.C., and J.P. Bekker 2008. Nathusius' pipistrelles (*Pipistrellus nathusii*) and other species of bats on offshore platforms in the Dutch sector of the North Sea. Lutra 51(1): 17-36.

Brabant, R., Y. Laurent, and B. Jonge Poerink. 2018. First ever detections of bats made by an acoustic recorder installed on the nacelle of offshore wind turbines in the North Sea. In: Degraer, S., Brabant, R., Rumes, B. & Vigin, L. (eds). Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Assessing and managing effect spheres of influence. Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, Brussels. 129-136.

Brabant, R., Y. Laurent, B.J. Poerink, and S. Degraer. 2020. Activity and behaviour of Nathusius' pipistrelle *Pipistrellus nathusii* at low and high altitude in a North Sea offshore wind farm. Acta Chiropterologica 21(2):341-348.

Carpenter, J.R., K.A. Williams, and E. Jenkins. 2021. Environmental stratification workgroup report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts. Report to the New York State Energy Research and Development Authority. Albany, NY. 14 pp. Available at: https://www.nyetwg.com/2020-workgroups.

Cook, A., K.A. Williams, E. Jenkins, J. Gulka, and J. Liner. 2021. Bird Workgroup Report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts. Report to the New York State Energy Research and Development Authority (NYSERDA). Albany, NY. 37 pp. Available at https://www.nyetwg.com/2020-workgroups.

Crichton, D. 1999. The risk triangle. In: Ingleton, J. (ed.), Natural disaster management. Tudor Rose, London. 102-103.

Cryan, P.M, and A.C. Brown. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation 139: 1–11.

Cryan, P.M, and R.M. Barclay. 2009. Causes of bat fatalities at wind turbines: hypotheses and predictions. Journal of Mammalogy 90: 1330–1340.

Cryan, P.M., P.M. Gorresen., C.D. Hein., M.R. Schirmacher., R.H. Diehl., M.M. Huso., D.T.S. Hayman., P.D. Fricker., F.J. Bonaccorso., D.H. Johnson., K. Heist, and D.C. Dalton. 2014. Behavior of bats at wind turbines. Proceedings of the National Academy of Sciences 111: 15126–15131.

Degraer, S., Z.L. Hutchison, C. LoBue, K.A. Williams, J. Gulka, and E. Jenkins. 2021. Benthos Workgroup Report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts. Report to the New York State Energy Research and Development Authority (NYSERDA). Albany, NY. 45 pp. Available at http://www.nyetwg.com/2020-workgroups.

Dowling, Z., P. R. Sievert, E. Baldwin, L. Johnson, S. von Oettingen, and J. Reichard. 2017. Flight activity and offshore movements of nano-tagged bats on Martha's Vineyard, MA. OCS Study BOEM 2017-054. U.S. Department of the Interior, Bureau of Ocean Energy Management, Sterling, Virginia. 39 pp. Available at: https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Renewable-Energy/Flight-Activity-and-Offshore-Movements-of-Nano-Tagged-Bats-on-Martha%27s-Vineyard%2C-MA.pdf

Electrical Power Research Institute. 2020. Population-level risk to hoary bats amid continued wind energy development: Assessing fatality reduction targets under broad uncertainty. Final report 3002017671. Palo Alto, CA. 75 pp. Available here: https://www.epri.com/research/products/000000003002017671

Frick, W.F., E.F. Baerwald., J.F. Pollock., R.M.R. Barclay., J.A. Szymanski., T.J. Weller., A.L. Russell., S.C. Loeb., R.A. Medellin, and L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. Biological Conservation 209: 172–177.

Hatch, S.K., E.E. Connelly., T.J. Divoll., I.J. Stenhouse, and K.A. Williams. 2013. Offshore observations of eastern red bats (*Lasiurus borealis*) in the mid-Atlantic United States using multiple survey methods. PLoS One 8: 1–8.

Hawkins, A.D., C. Johnson, and A.N. Popper. 2020. How to set sound exposure criteria for fishes. The Journal of the Acoustical Society of America 147: 1762-1777.

Hein, C.D. 2017. Monitoring bats. In: M. Perrow (ed). Wildlife and wind farms, conflicts and solutions, Volume 2. Pelagic Publishing, Exeter. 31–57.

Horn, J.W., E.B. Arnett, and T.H. Kunz. 2008. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72:123–132.

Kunz, T.H., E.B. Arnett., W.P. Erickson., A.R. Hoar., G.D. Johnson., R.P. Larkin., M.D. Strickland., R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and Evolution 5: 315–324.

Lagerveld S., B. Jonge Poerink, P. de Vries. 2015. Monitoring bat activity at the Dutch EEZ in 2014. IMARES Report C094/15. 33 pp. Available at: https://research.wur.nl/en/publications/monitoring-bat-activity-at-the-dutch-eez-in-2014

Lagerveld S., C.A. Noort, L. Meesters, L. Bach, P. Bach, S.C.V. Geelhoed. 2020. Assessing fatality risk of bats at offshore wind turbines. Wageningen Marine Research report C025/20. Report to Project WOZEP, the Dutch Governmental Offshore Wind Ecological Programme. 39 pp. Available at: https://doi.org/10.18174/518591

Molis, M., R. Hill., O. Huppop., L. Bach., T. Coppack., S. Pelletier., T. Dittmann, and A. Schultz. Measuring bird and bat collision and avoidance. In: Perrow, M. (ed). Wildlife and wind farms, conflicts and solutions, Volume 4. Pelagic Publishing, Exeter. 167–206.

Nielsen, K.S. 2018. Integration of wildlife detection and deterrent systems in wind power plants. Report to the American Wind Wildlife Institute (AWWI), Washington, D.C. 21 pp. Available at: https://awwi.org/resources/technology-integration-white-paper/

Nielsen, K.S., D. Young, and S. Webster. 2019. Guidance for potential hosts of wind-wildlife technologies and strategies. Report to the American Wind Wildlife Institute (AWWI), Washington, D.C. 31 pp. Available at: https://awwi.org/resources/host-site-guidance/

Pennsylvania Game Commission. 2013. Pennsylvania Game Commission wind energy voluntary cooperation agreement amendment I. 66 pp. Available here: https://www.pgc.pa.gov/InformationResources/AgencyBusinessCenter/WindEnergy/Documents/Amended%20Cooperative%20Agreement%20and%20Exhibits%20-%202013.pdf

Popper, A.N., L. Hice-Dunton, K. A. Williams, and E. Jenkins. 2021. Workgroup Report on Sound and Vibration Effects on Fishes and Aquatic Invertebrates for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts. Report to the New York State Energy Research and Development Authority (NYSERDA). Albany, NY. 20 pp. Available at www.nyetwg.com/2020-workgroups.

Richardson, S.M., P.R. Lintott., D.J. Hosken., T. Economou, and F. Mathews. 2021. Peaks in bat activity at turbines and the implications for mitigating the impact of wind energy developments on bats. Scientific Reports 11: 3636.

Ruiz-Miranda, C.R., L.I. Vilchis, and R.R. Swaisgood. 2020. Exit strategies for wildlife conservation: why they are rare and why every institution needs one. Frontiers in Ecology and the Environment 18(4): 203-210.

Sinclair, K., and E. DeGeorge. 2016. Framework for testing the effectiveness of bat and eagle impact-reduction strategies at wind energy projects. NREL/TP-5000-65624. Report to the National Renewable Energy Laboratory, Golden, CO. 40 pp. Available at: https://www.nrel.gov/docs/fy16osti/65624.pdf

Sjollema, A.L., J.E. Gates., R.H. Hilderbrand, and J. Sherwell. 2014. Offshore activity of bats along the Mid-Atlantic coast. Northeastern Naturalist 21: 154–163.

Smith, A. D., and S. R. McWilliams. 2016. Bat activity during autumn relates to atmospheric conditions: Implications for coastal wind energy development. Journal of Mammalogy 97: 1565–1577.

Solick D., D. Pham., K. Nasman, and K. Bay. 2020. Bat activity rates do not predict bat fatality rates at wind energy facilities. Acta Chiropterologica 22(1):135-146.

Southall, B., L. Morse, K.A. Williams, and E. Jenkins. 2021. Marine Mammals Workgroup Report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts. Report to the New York State Energy Research and Development Authority (NYSERDA). Albany, NY. 50 pp. Available at https://www.nyetwg.com/2020-workgroups.

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. Report to the U.S. Department of Energy, Topsham, Maine. 171 pp. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Stantec-2016-Bat-Monitoring.pdf

U.S. Department of Energy. 2015. Wind vision: a new era for wind power in the United States. Report DOE/GO-102015-4557. U.S. Department of Energy, Office of Scientific and Technical

Information. Oak Ridge, TN. 346 pp. Available at: https://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf

U.S. Fish and Wildlife Service. 2012. Land-based wind energy guidelines. 71 pp. Available at: https://www.fws.gov/ecological-services/es-library/pdfs/WEG_final.pdf

Weaver, S.P., A.K. Jones., C.D. Hein, and I. Castro-Arellano. 2020. Estimating bat fatality at a Texas wind energy facility: implications transcending the United States-Mexico border. Journal of Mammalogy 101: 1533 – 1541.

Appendix A. Workgroup Participants

Table A1. Workgroup members who attended one or more workgroup meetings and/or provided written comments on research priorities (listed in alphabetical order by first name).

Name	Affiliation
Brita Woeck	Ørsted
Caroline Byrne	Biodiversity Research Institute
Cathy Johnson	National Park Service
Christine Sutter	Natural Power
Cris Hein	National Renewable Energy Laboratory
Dave Phillips	Equinor
David Yates	Biodiversity Research Institute
Dustin Meattey	Biodiversity Research Institute
Dusty Miller	Black & Veatch
Ed Jenkins	Biodiversity Research Institute
Elizabeth Hansel	Vineyard Wind
Emily Hall	Seatuck
Gabe Reyes	United States Geological Survey
Jeff Clerc	Normandeau Associates
Jeff Herter	New York Department of State
Judy Dunscomb	The Nature Conservancy
Kate McClellan Press	New York State Energy Research & Development Authority
Kate Williams	Biodiversity Research Institute
Kathy Matthews	United States Fish and Wildlife Service
Louis Brzuzy	Shell New Energies
Mao Lin	Tetra Tech
Mark Ford	United States Geological Survey
Matt Robertson	Vineyard Wind
Michael Evans	Ørsted
Michael Whitby	Bat Conservation International
Michal Przybycin	B-finder EMPEKO S.A.
Mike True	Virginia Tech
Mona Khalil	United States Geological Survey
Nathan Schwab	Tetra Tech
Paul Phifer	Atlantic Shores Offshore Wind
Sarah Haggerty	Maine Audubon
Shannon Kearney	Connecticut Department of Energy and Environmental Protection
Taber Allison	American Wind Wildlife Institute
Trevor Peterson	Stantec Consulting Services Inc.
Wendy Jensen	Environmental Solutions and Innovations Inc.
Wing Goodale	Biodiversity Research Institute
Zara Dowling	University of Massachusetts Clean Energy Extension