OCS Study
BOEM 2023-051

Offshore Wind Energy Development and North Atlantic Right Whales

U.S. Department of the Interior

Bureau of Ocean Energy Management

Sterling, VA

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July 2023

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Prepared under BOEM IDIQ: 140M0121D0004, Task Order# 140M0121F0002
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Study concept, oversight, and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, D.C., under Obligation Number 140M0121D0004 with Blue World Research Institute.

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CITATION

Silber, GK, Dangerfield A, Smith J, Reeb D, Levenson JJ (Blue World Research Institute, Cocoa, FL). 2023. Offshore wind energy development and North Atlantic right whales. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 99 p. Obligation No.: 140M0121D0004. Report No.: OCS Study BOEM 2023-051.

ABOUT THE COVER

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List of Abbreviations and Acronyms

Short Form	Long Form
AMAPPS	Atlantic Marine Assessment Program for Protected Species
ASRG	Atlantic Scientific Review Group
BAG	Before-After-Gradient
BMP	Best Management Practices
BOEM	Bureau of Ocean Energy Management
BWRI	Blue World Research Institute
COP	Construction and Operations Plan
CSA	Canadian Space Agency
CSA	CSA Ocean Sciences Inc.
DFO	Fisheries and Oceans Canada
DMS	dimethyl sulfide
DOI	U.S. Department of the Interior
DST	decision support tool
ESA	Endangered Species Act
IUCN	International Union for Conservation of Nature
MMPA	Marine Mammal Protection Act
NARW	North Atlantic right whale
NARWSS	North Atlantic Right Whale Sighting Survey
NMFS	National Marine Fisheries Service, also NOAA Fisheries
NOAA	National Oceanic and Atmospheric Association
NYB	New York Bight
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OSW	offshore wind
PAM	passive acoustic monitoring
PCAD	Population Consequences of Acoustic Disturbance
PCoD	Population Consequences of Disturbance Population
PCoMS	Population Consequences of Multiple Stressors
photo-ID	photo identification
PSO	Protected Species Observer
RWSAS	Right Whale Sighting Advisory System
RWSC	The Regional Wildlife Science Collaborative for Offshore Wind
RWSE	Regional Wildlife Science Entity
SERDP	Strategic Environmental Research and Development Program
TC	Transport Canada
UAS	unmanned aerial systems
VHR	very high resolution
WEA	wind energy area

Summary

Overview

The climate crisis is fueling a growing demand in the U.S. for energy resources that are both domestic and renewable. The Biden-Harris Administration has responded by establishing a target of deploying 30 gigawatts of offshore wind generation by 2030. This target has resulted in a rapid expansion of offshore wind (OSW) energy development. The Bureau of Ocean Energy Management (BOEM) is the Federal agency tasked with ensuring energy resources on the U.S. Outer Continental Shelf (OCS) are developed responsibly. Atlantic wind energy areas (WEAs) that encompass these lease areas occur between 15 and 60 kilometers (km) offshore and extend from the Massachusetts to the North Carolina coasts. This region is also home to the critically endangered North Atlantic right whale (NARW), *Eubalaena glacialis.*

OSW energy development presents a range of potential stressors to NARW, including increased ocean traffic, noise, and habitat degradation. To better assess the contribution of OSW energy-related impacts to NARW, this report was commissioned to 1) summarize threats to NARW broadly and in the context of OSW development, 2) provide summaries of methodologies used and studies completed, ongoing, or planned to characterize NARW distribution, behavior, and relative abundance, and 3) solicit opinions from the NARW research community and the OSW industry on research needed to minimize OSW impacts on the NARW and to assess mitigation efforts. The information provided here is expected to contribute to the development of an interagency NARW and OSW strategy aimed at protecting and supporting the recovery of the NARW and the simultaneous responsible development of offshore wind energy.

This report contains the following:

- A summary of relevant completed, ongoing, or planned NARW research studies, especially those related to OSW impacts.
- A synthesis of the methodologies used to gather the information contributing to NARW and marine mammal threat and impact assessments.
- An overview of relevant literature and responses from an online survey of a group of representatives of the OSW energy industry, the NARW research community, environmental groups, and state and Federal agencies that provided information about current and planned (within the next five years) research efforts.
- A review of the status of the NARW population and descriptions of the data collection methods, analysis techniques, and modeling efforts used in population monitoring.
- Discussion on the potential impacts of OSW energy development on NARW, research aimed at assessing NARW responses to those impacts, and studies addressing ways to reduce the impacts.
- Concluding comments and recommendations for future action.

Problem Summary

The NARW population is among the smallest of all large whale species populations, numbering in the hundreds. Despite a slow but steady increase in abundance following international protections, new and ongoing threats have again reduced the NARW population size in the last decade. Primary threats to the population originate from commercial and industrial activities (including fishing and shipping activities). Because NARW range overlaps with coastal regions with large human population centers, large-scale commercial fisheries, and extensive shipping lanes, fishing gear entanglement and vessel collisions are leading causes of mortality. Regulatory measures have been instituted, or are being developed, in attempt to reduce these threats to the NARW population.

The development and operation of OSW farms may also present stressors to the NARW. These include noise (generated by site characterization, platform installation, operational activities, and associated vessel traffic), vessel collisions, and habitat changes due to the presence of wind turbine foundations, among others. Positive impacts are also anticipated, including, but not limited to, benefits of a transition to renewable energy and reduced greenhouse gas emissions to combat climate change, and increased detection, tracking, and situational awareness of the NARW through the advancement of alternative monitoring tools. Unlike those of fishing gear entanglements and vessel collisions, which are the major factors in NARW mortality, the long-term effects of OSW-associated stressors are still largely unknown. This knowledge gap is primarily due to the inherent difficulty of parameterizing biological outcomes of multiple stressors (e.g., noise, pollutants, and habitat disturbances). Nonetheless, potential impacts both positive and negative from OSW activities must be assessed and, where negative impacts exist, reduced (or eliminated) in scope and magnitude. Under the National Environmental Policy Act, and Endangered Species Act (ESA), and the Marine Mammal Protection Act, BOEM is obligated to identify and, under section 101(a)(5), mitigate OSW impacts to marine mammals.

Changing climate is also altering the location and occurrence of NARW prey and, in response, NARW distribution is shifting (e.g., Greene 2016). Studies are needed to distinguish the impacts of climate change, industry activities, and other factors and to understand how their individual and cumulative impacts might affect NARW occurrence, distribution, demographics, health, and behavior.

Solution Summary

Identifying, distinguishing, and quantifying the impact of OSW energy activities relative to other anthropogenic impacts and human-made and naturally occurring environmental shifts requires reliable data on NARW population trends, health, and behavior.

This report provides capsule reviews of research methods relevant to NARW research including 1) passive acoustic monitoring (PAM) (and associated PAM networks); 2) vessel and aircraft observation (including surveys on regional, state, and WEA scales); 3) individual photo-identification; 4) vision-enhanced observation (e.g., infrared and related technologies); 5) satellites and drones; 6) tagging and telemetry; 7) risk, disturbance, and cumulative effects modeling; 8) environmental monitoring (e.g., oceanographic, ecological, and prey studies); 9) individual stress and health analyses; 10) biopsy sampling to determine genetics and individual identification; and 11) behavioral response studies. Survey respondents commented on the utility of, the increased use of, and/or the need to improve upon these (and other) approaches relative to NARW occurrence, distribution, and population monitoring.

Visual and underwater passive acoustic techniques remain mainstays in marine mammal research and in NARW studies, and most survey respondents focused on those techniques. These approaches are employed (in completed and ongoing studies described here) on site-specific and broad scales to determine NARW occurrence and spatial distribution. These data, along with long-term photo-identification data, in turn, are used in various population assessment and modeling studies, and characterizations of changes in whale distribution.

Relatively recent advances in health assessment techniques have resulted in their increased application to NARW research. At this time, tagging and satellite-based remote-sensing approaches appear to be used relatively sparingly in the study of NARW due to various challenges and considerations, while underwater gliders (used to collect ecosystem and whale acoustic data) and aerial drones are receiving increased use. Studies identified in the survey also include the quantifying of sound levels from OSW activities and identifying and testing ways to reduce source levels. Advances in hardware, big-data processing, and emerging data collection, analytical, and modeling approaches have the potential to enhance and supplement traditional and previously used data collecting methods.

Results of the survey, along with overviews of the literature and ongoing and planned NARW studies, indicate that much attention is now being focused on modeling efforts that study anthropogenic effects on marine mammals and, specifically, NARW. Several approaches, again as reflected in survey responses, are covered in this report, including 1) distribution and/or spatial density and occurrence modeling to describe marine mammal spatiotemporal occurrence patterns, 2) risk assessments that overlay patterns of human activities and their inherent stressors with marine mammal habitat models, 3) impact modeling that estimates stressor exposure risks and their consequences, 4) disturbance modeling, and 5) predictive modeling using animal occurrence datasets together with oceanographic, biological, and physiographic data. Survey respondents indicated that, among other things, though useful in estimating impacts, such models can face challenges in quantifying certain variables where data-poor situations exist; however, these efforts could be improved by additional data collection, improved data streams, and mining of existing datasets to fill data gaps.

The report concludes by considering various data collection and analysis approaches and, together with commentary from survey respondents, addresses how research plans might be developed to assess OSW impacts and how potential impacts on NARW could be avoided or minimized. The results encourage the development of comprehensive interagency plans; increased data sharing between academia, government, and industry to maximize the amount of data available; increased analytical rigor; and development and implementation of directed studies of NARW population-level changes from OSW activities.

1 Introduction

The growing demand for domestic energy development has prompted the rapid expansion of offshore wind (OSW) in the United States (U.S.). The Bureau of Ocean Energy Management (BOEM) is responsible for managing the U.S. Outer Continental Shelf (OCS) energy resource development in an environmentally responsible way. At the time of this study, 17 Atlantic OSW lease sites have been completed or are under review. Wind energy areas (WEAs) in BOEM's Atlantic OCS Region are approximately 15–60 km from the coasts of Massachusetts, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina (BOEM 2021a). These coastal waters are also used by the critically endangered North Atlantic right whale (NARW), *Eubalaena glacialis*, and a host of other marine mammal species.

Underwater noise, vessel strikes, and entanglement are threats or stressors to NARWs' critically endangered population (Cooke 2020). OSW development and production may increase these threats through construction or operational noise, increased vessel traffic, or potential entanglement around proposed floating platforms. Many scientists are currently monitoring the NARW population status to assess and reduce impacts from OSW energy development and other stressors, including climate change. To advance these efforts, BOEM sought to 1) summarize threats to NARW broadly and in the context of OSW development; 2) provide summaries of methodologies used and studies completed, ongoing, or planned to characterize NARW distribution, behavior, and relative abundance; and 3) solicit opinions from the NARW research community and OSW industry on research needed to minimize OSW impacts on the NARW and to assess mitigation efforts.

To accomplish this, BOEM contracted with Blue World Research Institute, Inc. (BWRI) to synthesize current NARW population monitoring practices and in-use or developing methods used to understand or reduce OSW-related impacts on the population. In addition to this summary, BWRI canvassed OSW energy industry representatives, NARW researchers, environmental groups, and others about their ongoing and planned work and their views on innovations that may be applied in a one- to five-year time horizon. Emerging or novel uses of existing methodologies that study NARW occurrence, distribution, and health were emphasized, as were potential mitigation measures and technologies. Note that an overview of OSW and NARW-related management actions and the potential impact of OSW energy development on other species are outside the scope of this review and can be found elsewhere.[1]

[1] Generally speaking, NEPA-mandated Environmental Impact Statements (for a recent example, see BOEM 2021b) and related documents required under the National Environmental Policy Act for project initiation are reasonable sources of descriptions of affected species, possible impacts, and mitigation and monitoring measures.

2 Background

2.1 Approach in Preparing this Summary

BWRI accessed literature to summarize the relevant NARW and marine mammal studies and current research into OSW activity impacts. On 17 December 2021, BOEM emailed a broad distribution list (213 recipients) comprising the NARW research community, wind energy company representatives, and relevant environmental organizations about its intent to summarize current NARW research, including mitigation and monitoring measures for OSW development. On 20 December 2021, BWRI invited members of this distribution list and their organizations (Figure 1) to participate in an online survey designed to gather information on current and planned studies, as well as future research needs. To ensure adequate participation in the survey, BWRI sent a reminder email on 7 January 2022. The assessment questions are provided in Appendix A.

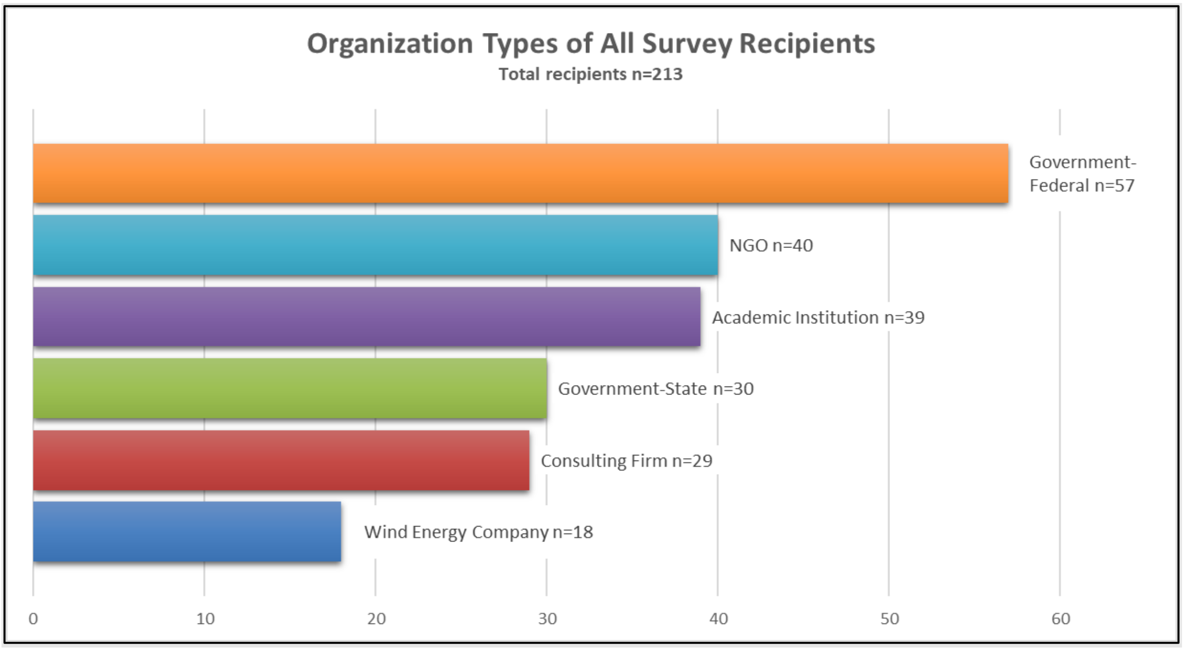

Figure 1. Number of individuals from each organization who were asked to participate in the survey.

As of 23 January 2022, 39 individuals responded to the survey. Eleven respondents were affiliated with Federal government agencies, eight with non-governmental organizations, eight with academic institutions, six with consulting firms or (non-OSW) companies, four with state government agencies, and two with wind energy corporations (Figure 2). Multiple people responded from some organizations. The survey included a question asking if participants were interested in follow-up conversations to gather more detailed information. Sixteen responders indicated they were interested in follow-up conversations, seven asked not to be contacted, and the remainder did not respond. BWRI conducted some follow-up interviews to gather details about individual survey responses and other information for this report.

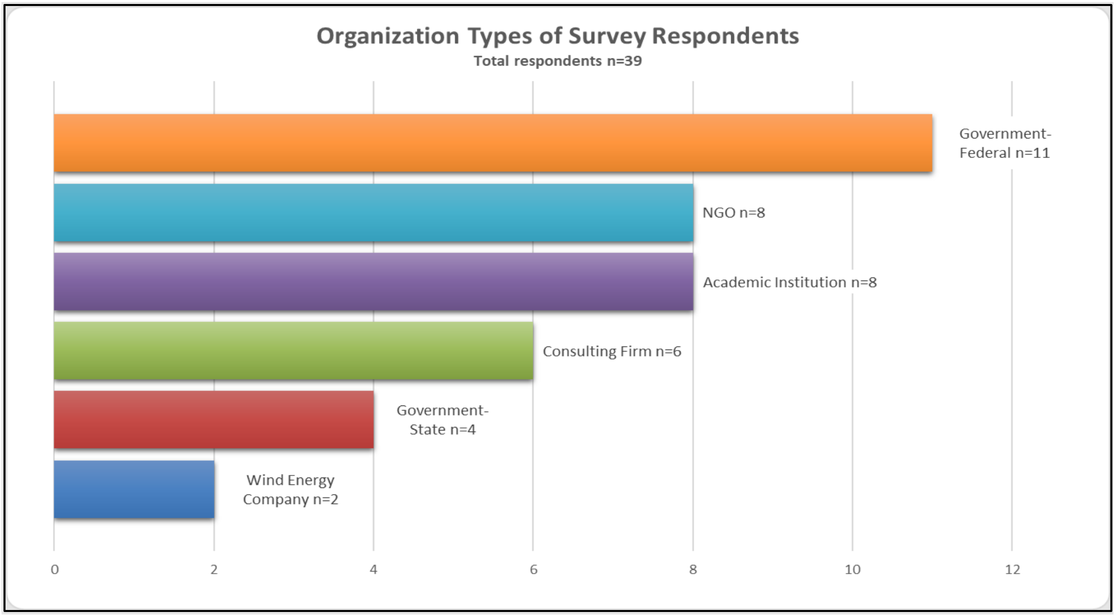

Figure 2. Number of individuals from each organization type who responded to the survey.

All respondents chose a defined category that described their research. As shown in Figure 3, fourteen selected "NARW population status and monitoring;" ten selected "assessing impacts to NARWs from wind energy development and/or detecting population effects from impacts;" three selected "new or emerging approaches for reducing impacts to NARW;" two selected "assessing the relative effectiveness of mitigation measures;" three selected that their research covered "all options;" and seven chose "other" or provided a different response.

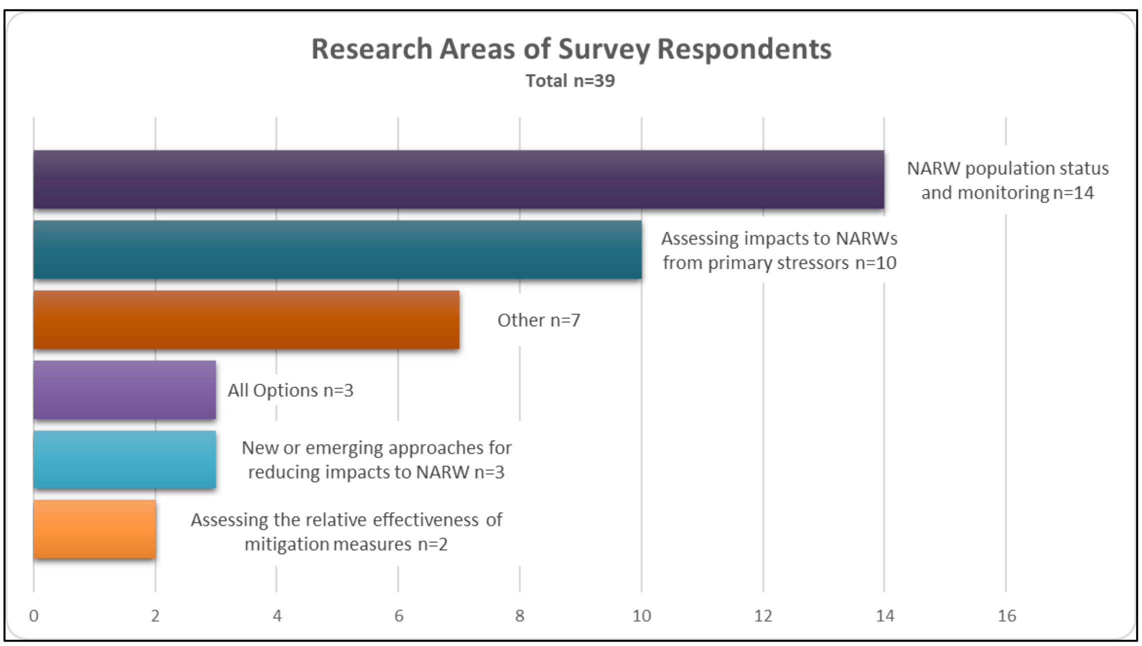

Figure 3. Research areas indicated by the survey responders.

2.1.1 Current Status of the North Atlantic Right Whale

NARWs are among the most endangered of all large whale species (Marine Mammal Commission 2022). The species was listed as Endangered under the Endangered Species Act (ESA) in 1970. It has been slow to recover from severe depletion by heavy commercial whaling and, more recently, persistent mortality and serious injury from entanglement in fishing gear and vessel collisions continue to undermine population recovery. The population slightly, but steadily, increased during the 1990s to mid-2010s but has declined in the last several years (Thomas et al. 2015, Hayes et al. 2022, Pettis et al. 2022).

When international protection for right whales was established in 1935, the NARW population may have numbered fewer than 100 individuals (Reeves et al. 1992, Kenney et al. 1995). Increased scientific attention in the early 1980s and 1990s (i.e., increased emphasis on abundance surveys and birth and death rates) indicated the population contained approximately 300 individuals. Studies in the mid-1990s to early-2010s indicated modest, but incremental, population growth of about 2.8% per year (Cooke 2020). This growth increased abundance from around 300 to 450 individuals with a minimum estimate of 295 individuals in 1992 (Knowlton et al. 1994, Blaylock et al. 1995), at least 313 individuals in 2002, a minimum population of 482 in 2010, and at least 458 individuals in 2011 (Pace et al. 2017). Though encouraging, this was much lower than the 7% growth seen in the Southern right whale population over the same period (Carroll et al. 2013, Jackson et al. 2016).

By the mid-2010s, NARW population began gradually declining. The minimum population estimate as of May 2022 was 364 individuals (Hayes et al. 2022). Based on figures provided by the Right Whale Consortium, population decline in the last decade is estimated at 26%, and the most recent assessment of individuals was 336 (95% confidence range +/- 14) in 2020 (Pettis et al. 2022). The observed average number of deaths and serious injuries for the species routinely exceeds the Potential Biological Removal as allowed for fisheries by the Marine Mammal Protection Act (MMPA) (0.7 whales per year, NMFS 2022a). In July 2020, the International Union for Conservation of Nature (IUCN) elevated the NARW from ”Endangered” to ”Critically Endangered” on its Red List (IUCN 2020).

2.2 Known and Documented Deaths from Vessels and Fishing Gear

NARW range overlaps with regions of concentrated human activities including commercial fishing grounds, and high-traffic shipping lanes servicing seaports along the U.S. and Canadian eastern seaboard. NARW population growth has slowed due to a combination of relatively low interannual birth rates, habitat degradation, and other unknown causes. However, the leading causes of mortality are death and serious injury from fishing gear entanglement and vessel collisions (Hayes et al. 2022).

Seventy NARW deaths were documented between 2003 and 2018 in waters between Florida and the Gulf of St. Lawrence, Canada. The cause of death was determined in 43 instances: 22 (57.9%) from entanglement and 16 (42.1%) from vessel strikes (Sharp et al. 2019). Recent right whale deaths have renewed concern for the population. Henry et al. (2022) reported 20 serious injuries and 22 mortalities between 2016 and 2020 that were attributed to either vessel strikes or entanglement in fishing gear. Investigations have been, and are, underway using Unusual Mortality Event protocols.Broadly speaking, not all deaths are detected, and population trend analyses indicate that the actual number of deaths is likely three times higher than the minimum number detected (Pace et al. 2021).

2.3 Actions to Reduce Threats to NARW from Entanglement and Vessel Collisions

Historically, the government has implemented measures to reduce the number of deaths and injuries from commercial fishing gear entanglement and vessel strikes. Authority provided under the ESA and MMPA has enabled NMFS to issue various regulations aimed at reducing fishing gear entanglements, including gear modifications and area closures (e.g., 72 FR 57104; 80 FR 30367; 86 FR 51970; NMFS and NOAA 2021; NMFS 2022b). Various measures to reduce vessel collisions with right whales have also been implemented, including vessel routing measures (e.g., Silber et al. 2012) and vessel speed restrictions (NMFS and NOAA 2008, 73 FR 60173; and subsequent modifications to the speed restriction rulemaking, NMFS and NOAA 2013, 78 FR 73726; NMFS and NOAA 2014, 79 FR 34245). Descriptions of these measures are well documented (in, for example, NMFS 2022b, and elsewhere), and will not be reviewed here. NMFS recently proposed rulemaking to amend its vessel speed rule (NMFS and NOAA 2022, 87 Fed. Reg. 46921) and announced its draft Ropeless Roadmap (NEFSC 2022) to help reduce the amount of fishing line in the water column.

2.4 Impacts to NARWs from Wind Energy Construction Projects

OSW energy generation is expected to reduce greenhouse gas emission rates relative to those currently produced by other energy sources (e.g., fossil fuels). However, OSW site assessment, construction, and operational phase activities may negatively affect NARWs. OSW energy development activities can generate high-amplitude sounds during pile-driving (see, for example, ISO 2017, Tsouvales 2020) and limited contributions during site characterization surveys (e.g., high-resolution geophysical surveys; Ruppel et al. 2022). Exposure to sound levels from OSW activities may result in disruption of normal behavior or displacement from key areas such as feeding grounds or other preferred habitats (e.g., NRC 2003, 2005, Stöber and Thomsen 2019). Increased vessel traffic associated with platform construction, maintenance, and operation increases the risk of vessels striking NARWs. OSW platform construction could also impact NARWs by changing benthic and pelagic habitats, altering ecosystem services (e.g., Galparsoro et al., 2022), increasing vessel pollution, and releasing contaminants from seabed sediments (e.g., Bailey et al. 2014, BOEM 2018a, Kraus et al. 2019). Entanglement risk (primary, secondary, tertiary) to marine mammals from floating offshore wind facilities in some settings may pose additional challenges as that type of platform receives increased use (Harnois et al. 2015). Changes in NARW distribution resulting from the effects of climate change (e.g., Record et al. 2019, Pershing and Pendleton 2021, Meyer-Gutbrod et al. 2021) may compound adverse effects through heightened exposure to other anthropogenic activities in other locations. More complete discussions of potential environmental impacts from OSW activities can be found in Bailey et al. (2014) and BOEM (2018a).

2.4.1 Reducing Impacts from OSW Activities

2.4.1.1 Legal Authorities

BOEM and the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) principally oversee OSW development in U.S. waters. BOEM derives its authority from the Outer Continental Shelf Lands Act (OCSLA), enacted by Congress in 1953. The primary purpose of the Act is to facilitate leasing offshore mineral and energy resources. The OCSLA gives authority to the Secretary of the U.S. Department of the Interior (DOI) to manage and make available "all submerged lands beyond the lands reserved to the States up to the edge of the United States under its jurisdiction and control." The Energy Policy Act of 2005, an amendment to the OCLA granted the DOI lead management authority for marine renewable energy projects on Federal offshore lands.

In 2009, BOEM's predecessor, the Minerals Management Service, issued regulations for the OCS Renewable Energy Program, which provided a framework for issuing leases, easements, and rights-of-way for OCS activities that support the production and transmission of renewable energy, including OSW, ocean wave energy, and ocean current energy. BOEM is the lead agency within DOI responsible for implementing these regulations. Under NEPA, BOEM is also required to assess the environmental impacts of its actions and analyze alternatives.

The ESA charged the Secretary of Commerce, through NMFS, with the conservation and recovery of endangered and threatened marine species. This goal is accomplished by, among other things, developing and implementing recovery plans, designating critical habitats, conducting status reviews, and issuing research permits. Under Section 7 of the ESA, NMFS consults with other Federal agencies to determine whether their activities, including activities they may authorize, fund, or carry out, may affect ESA-listed species or their designated critical habitat. If the activity is likely to adversely affect a listed species, formal consultation is initiated. The resulting biological opinion may include conservation recommendations to further the recovery of the listed species and/or reasonable and prudent measures to minimize the incidental taking of listed species.

Under the MMPA, the Secretary of Commerce, through NMFS, is responsible for the protection and conservation of marine mammals and the ecosystems of which they are a part. NMFS implements its responsibilities under the MMPA by assessing marine mammal populations, developing annual stock assessment reports, coordinating the activities of marine mammal stranding networks, and issuing permits for research and captive display of marine mammals. NMFS may also authorize the taking of marine mammals incidental to other human activities, including OSW development, through its Incidental Harassment and Incidental Take Authorization program (NMFS 2020b).

In Canadian waters, the Department of Fisheries and Oceans handles endangered and depleted marine mammals, as delegated by the Species at Risk Act.

2.4.2 Reducing Potential Biological Effects from OSW Activities

BOEM and other agencies take actions under the respective authorities to identify and negative impacts of OSW on marine animals and their habitats (see, for example, BOEM 2018 a & 2018 b, 2020, 2021b, and summaries in Appendix B)[2]. These mitigation measures are outlined in National Environmental Policy Act-required Environmental Impact Statements, NMFS-issued incidental take and harassment authorizations, and BOEM-issued mitigation guidelines, leases, and permits.

For example, because noise introduced in the water column during wind farm development can impact marine life, operators are required to adhere to certain protocols and regulations to reduce noise. These include, in some instances and locations, seasonal and time-of-day restrictions on pile-driving operations, a '"soft start" ramp-up of pile-driving activities, cessation of activities when marine mammals are observed near the site, and the use of noise reduction and attenuation devices to minimize the levels and extent of emitted sound. They must also use visual and acoustic monitoring to establish marine mammal monitoring and exclusion zones. BOEM also requires operators to submit for review a Construction and Operations Plan (COP) with specific descriptions of overall objectives, proposed activities, schedule and timetables, and commercial lease stipulations and compliance. BOEM provides guidance on the content of COPs (BOEM 2020).

Outside these legal frameworks, other organizations have developed measures to reduce the potential negative impacts of OSW development on marine life. For example, in May 2014, three not-for-profit environmental groups (plus four additional endorsing organizations) entered into an agreement with wind developer Deepwater Wind regarding steps that can be taken to reduce impacts on NARW during certain OSW site assessments and characterization activities (Grybowski et al. 2014). Although not legally binding and specific only to the Rhode Island/Massachusetts WEA, the co-signers identified at least six specific measures the developer was to utilize in site survey phases. Measures centered primarily on seasonal adjustments to operations based on NARW north-south migration periods, use of visual

[2] These requirements are also specified in wind energy Incidental Harassment Authorizations (IHAs) (for a recent example, see NMFS 2019); project environmental impact statements (for a recent example, see BOEM 2021b) and related documents.

observers during operations, and exclusion zone sizes. Such side agreements might be considered and expanded by other operators in other locations; however, they may not be reasonably applicable in all OSW site situations, may not appeal to all operators, and, as noted, are not legally binding.

3 Current Status of Methodologies Used to Assess Potential Negative Impacts of Offshore Wind

To identify and quantify the impacts that OSW activities have on marine mammals, particularly NARWs, Before-After-Control-Impact studies are needed that compare marine mammal abundance, density, distribution, population trends, health, and behavior before, during, and after OSW activities in the context of natural variability.

There is an increasing need to monitor the distribution and density of NARWs because warming ocean temperatures are causing their prey and habitat-use patterns to change location (Greene 2016, Pershing and Stamieszkin 2020, Meyer-Gutbrod et al. 2021), which compounds existing, significant interannual variation. Monitoring efforts may assist in determining changes in distribution as influenced by industry activities, climate change, or other factors. It is, therefore, important to understand the collection methods, data types, and analysis techniques used in baseline marine mammal research.

The majority of marine mammal research historically relied on a handful of basic visual and acoustic techniques to study species distribution, occurrence, and behavior. Visual surveys conducted from vessels, aircraft, and shorelines, photo-identification (photo-ID) of individuals, and passive acoustic monitoring have and continue to be the foundation for the study of marine mammal biology, including that of the NARW.

However, in the last few decades, advances in hardware and software capabilities, artificial intelligence, and big-data processing have improved insights into and understanding of marine biology and oceanography. Such advances are now being applied to improve the understanding of the basic biology and assessments and mitigation of human impacts on marine mammals and the NARW.

This overview covers both basic and new technology-enhanced methods, yet an attempt to provide a fully comprehensive summary of decades-long marine mammal research will certainly be incomplete. Nevertheless, the summary represents a characterization of the state of play of current and recently completed research, as much of the information comes from our canvassing of the NARW research community. The overview also emphasizes BOEM-funded studies as a means to encapsulate BOEM's research programs regarding OSW activities and NARWs.

This report groups research discussions by 1) data collection methodologies and survey types, 2) modeling and analysis techniques, 3) detecting and assessing biological impacts from OSW energy development and other human activities 4) impact mitigation, and 5) considerations for future actions. Sections 4 through 7 review completed or ongoing studies for each subtopic and a review of the research communities' responses, observations, and recommendations that came from our survey. Section 8 contains a discussion of considerations for future actions and research areas. Brief summaries of completed or ongoing studies are provided in Appendix C.

The studies discussed and summarized herein are diverse. Some, such as population status and distribution monitoring, are ongoing, long time-series studies. Some, such as recent modeling efforts, seek to build upon or modify existing tools; others are devoted to verifying frequently used techniques and approaches. BOEM, its many collaborators, and numerous organizations have invested considerable funding and effort into these studies.

3.1 Relevant Workshops and Working Groups

Numerous recent workshops and recently convened workgroups have addressed issues closely related to those covered in this report. Summaries of the objectives, key findings, and conclusions and/or recommendations for some of these workshops and working groups are provided in Appendix B and their findings have been incorporated into the text as appropriate.

These efforts include the following:

- March 2017 *Best Management Practices Workshop for Atlantic Offshore Wind Facilities and Marine Protected Species* (BOEM 2018)
- May 2018 *Workshop on a Framework for Studying the Effects of Offshore Wind Development on Marine Mammals and Turtles* (Kraus et al. 2019)
- Periodic meetings of the Atlantic Scientific Review Group (ASRG) to advise on the status of marine mammal stocks
- June 2019 *Health Assessment Workshop for North Atlantic Right Whales* (Fauquier et al. 2020)
- October 2020 *Workshop on New York Bight Passive Acoustic Monitoring* (WCS 2021)
- November 2020 *Workshop on the State of the Science on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts* (Southall et al. 2021).

The Regional Wildlife Science Collaborative for Offshore Wind (RWSC), formerly the Regional Wildlife Science Entity (RWSE), is overseen by a stakeholder Steering Committee and has organized subcommittees of experts focused on marine wildlife as related to OSW activities. An initial charge of all RWSC subcommittees, including the Subcommittee on Marine Mammals, is "To collaboratively and effectively conduct and coordinate relevant, credible, and efficient regional monitoring and research of wildlife and marine ecosystems that supports the advancement of environmentally responsible and cost-efficient offshore wind power development activities in U.S. Atlantic waters." (RWSC 2023). The RWSC's marine mammal subcommittee convened its inaugural meetings in fall-winter 2021–2022, with a work product expected by 2023.

4 Data Collection Methodologies and Survey Types

4.1 Passive Acoustic Monitoring

4.1.1 Overview of Completed or Ongoing Studies

Studies in the 1970s and 1980s first used underwater listening devices to systematically determine the presence of vocalizing large whale species (e.g., Winn et al. 1975, Clark et al. 1986). Aided by steady improvements in sensing devices, passive acoustic monitoring (PAM) data are now routinely used to analyze whale abundance, distribution, and movement patterns at the population level and movements of individuals. PAM surveys can provide data on local scales (e.g., Clark et al. 2005) and, with arrays of multiple sensors, on regional scales (e.g., Soldevilla et al. 2014, Van Parijs et al. 2015) and, for example, entire coastlines (e.g., Davis et al. 2017). PAM technologies are highly cost-effective, can gather data continuously, and are less affected by environmental conditions (e.g., high sea states, periods of low visibility), and are safer than vessel- and aircraft-based research. Analysis of cetacean occurrence and distribution information can be derived from archived or near real-time acoustic data and can provide long-term records of marine mammal occurrence and distribution. In addition, multiple sensors used in relatively close proximity to each other can be used to localize vocalizing whales; this has application to OSW mitigation efforts that rely on detecting whether an individual whale is within a certain zone of impact.

Increasingly, autonomous underwater gliders equipped with oceanographic and acoustic sensors are being used to detect whale presence over broad areas (e.g., Darling et al. 2020) and specific locations (Baumgartner and Lin 2019). In contrast to stationary PAM devices, gliders are mobile and can be remotely directed to go anywhere. They are particularly useful for short-term observations and can easily monitor for a fixed period, but not at a fixed location, such as during OSW construction. Studies using gliders have been used to determine baleen whale presence in near-real time (Baumgartner et al. (2020, 2021) to identify right whales in Canadian waters (Moloney and Constable 2021), and to calibrate the accuracy and detection range of moored acoustic detection buoys (Baumgartner and Lin 2019).

The vast amounts of acoustic data routinely collected by large PAM networks are typically added to established repositories (e.g., NOAA and NCEI 2017), which create opportunities for a variety of retrospective analyses (Wall et al. 2021). Some data centers, such as ECO-PAM, graphically display the call detection locations of several large whale species in real-time and year-round (e.g., Bailey and Baumgartner 2021, Robots4Whales 2023, ECO-PAM project 2022).

Though highly useful and cost-effective, PAM relies on animals vocalizing within the instrument's detection range. Therefore, acoustic data cannot confirm that whales are absent in a certain vicinity (e.g., Fiedler et al. 2018) nor can they be used for such information as estimating total whale abundance or population size. This limitation is particularly relevant to the acoustically cryptic NARW, especially mothers and calves for whose vocalizations are unreliable.

Nonetheless, ways to improve the sophistication and utility of acoustic monitoring techniques are continuously being sought. Several recent studies aim to validate collected data (e.g., confirm species-specific calls) (e.g., Baumgartner and Lin 2019), improve detection equipment and approaches, and characterize PAM best use practices (e.g., Van Parijs et al. 2021). Newer PAM systems are being evaluated for whale call detection probabilities within given ranges, bearing accuracy, and range and stability of the radio communications (e.g., Palmer et al. 2021; Wood 2020, 2021).

Recommendations for standardizing and archiving data (Wall et al. 2021), PAM methodologies, types of PAM equipment, sensor geographic placement, and related topics are provided elsewhere (e.g., Van Parijs et al. 2021) and no further elaboration is provided here. Similarly, we defer to Roch et al. (2013) and Roch et al. (2016) and Tethys (2012) for information about the development of metadata standards, documentation, and user software for PAM dataset aimed at facilitating wider PAM studies throughout the community.

4.1.2 Survey Responses About PAM

By far, most survey respondents commented on, and expressed the virtues of, PAM technologies. This may partially reflect that the people and organizations surveyed are involved in PAM data collection and analysis, use acoustically derived data for other purposes, such as distribution modeling, or it may reflect that PAM is a popular widely used method. Respondents noted that PAM approaches can, among other things, provide information on NARW and other whale species' distribution patterns, monitor specific sites and large geographic areas cost-effectively, and detect marine mammal presence during active industrial operations.

Indicating the need to detect large-scale shifts in NARW distribution and better understand interannual variability, many respondents emphasized the need for sampling on larger geographic spatial scales than those at present by using multiple-system arrays, particularly in areas where little is known about NARW habitat use, occupancy, and residence times. For example, one respondent expressed the need for "[e]nsuring there is a network of PAM within the NARW range as this has been shown to be [an] important approach for monitoring the movements and seasonal occurrence of NARW and will assist in differentiating the effects of offshore wind farms from other factors."

Another respondent indicated that acoustic sensors could be placed on windfarm platforms themselves to monitor during routine maintenance activities. One mentioned the importance of developing real-time PAM systems in his program's study area to help quickly implement mitigation measures.

As noted, there are large-scale studies using permanently mounted, multi-sensor acoustic arrays that collect data continuously and result in exceptionally large datasets. Several responders identified the need to facilitate analyses of these datasets by, for example, improving data processing to make analyses more rapid.

One respondent mentioned building artificial intelligence models to recognize the calls of individual whales using newly collected and historical acoustic datasets.

Interestingly, only two responders called for improvements or updates to existing acoustic technology, such as advancing sensor equipment design and capabilities, progressing species-level detection software, or enhancing processing methodologies. However, since PAM systems have been used for decades, and are always undergoing improvements by their manufacturers and operators, such improvements may have been taken for granted and not in need of highlighting by survey responders.

Of the two responders who commented on technology improvement, one advocated investigating emergent 3D vector hydrophone sensors. This technology can determine the direction in which a sound wave is traveling using measurements made from a single point. Prototype testing is underway to assess noise from the construction and operation of offshore wind turbines and track vocalizing marine mammals in real time, including NARWs. The next steps for research include measuring noise from large numbers of wind turbines under construction or in operation and using 3D vector hydrophone sensors to monitor marine mammal presence in real time. The other responder called for lower costs on fixed systems and advocated for advancements in vector hydrophone sensors.

4.2 Vessel and Aerial Monitoring

4.2.1 Overview of Completed or Ongoing Studies

Marine mammals are chiefly detected by humans using visual and acoustic techniques. Vessel-, aircraft-, and land-based and site-specific visual observations are limited by poor weather and high sea state conditions. Nonetheless, they continue to be a mainstay of marine mammal studies and remain the state-of-the-art technique to monitor marine mammal “exclusion zones” near OSW energy development and other industrial sites and are one of the only methods available to determine the behavior of individuals, identify individuals, and take biological samples (Oleson et al. 2020).

While vessel and aerial monitoring provide important information on NARWs, they are more expensive and have higher safety risks than other monitoring techniques. Oleson et al. (2020) recommended integrating PAM and visual survey techniques to take advantage of their complementary strengths to collect data most efficiently and cost-effectively. For example, Oleson et al. (2020) suggested using PAM to detect the presence of NARW and trigger a more targeted, visual survey or biological sampling study.

4.2.2 Survey Responses About Vessel and Aerial Monitoring

4.2.2.1 Vessel-based Surveys

Few survey responders recommended increasing or improving vessel-based surveys. They mostly acknowledged that boat surveys can be costly and provide only a snapshot of whale occurrence. However, one commenter noted that boat surveys were important tools for studying whale behavior to, for example, better understand if whales are engaged in feeding, or how a whale responds when it nears a wind turbine platform.

4.2.2.2 Aerial Monitoring

Many respondents particularly noted the importance of aircraft surveys to monitor NARW distribution, changes in distribution, and collect data for photo-ID studies. One responder said that “[a]erial surveys are ultimately the best way to feed the distribution models. Without aerial survey data we will have no way to assess the impacts of wind energy development and climate change on right whale habitat use.” Another suggested monitoring efforts should be harmonized across monitoring platforms and incorporate technological advancements (particularly for visual monitoring) as they become available.

The survey group also emphasized the role aerial survey data play in assessing OSW development impacts. It was noted, for example, that BOEM should work with NMFS to ensure sufficient aerial surveys are conducted in WEAs and broader regions because they could detect changes in animal presence and foraging behavior and help determine if those changes are a result of OSW development or some other factor. Another commented that “[t]he highest priority is maintaining the aerial surveys. We then need to prioritize analyses of these data, including species distribution modeling, demographic analyses, site fidelity, risk assessment, and trade-off analyses.”

However, views about aerial surveys were not consistent among all responders: some called for more aerial surveys, while others suggested they should be replaced with PAM technologies. One person, for example, noted “manned aerial surveys . . . should [move] into the past” in favor of “unmanned [sic] vehicles (drones in the air and gliders in the water) that are safer instruments for recording animals and [whose] technology seems to be there to get good data from these systems.”

4.3 Photo-ID Studies

4.3.1 Overview of Completed or Ongoing Studies

Photo-ID of individuals is a standard methodology in marine mammal and NARW studies. Distribution studies using aircraft- and vessel-based photo ID surveys remain one of the most powerful means to assess marine mammal abundance, population status, trends in abundance, various demographic features (e.g., longevity, age at first calving), health assessments, and habitat use.

Numerous studies (e.g., Kraus et al. 2016, Crowe et al. 2021, Pettis et al. 2021) rely on this important technique and attest to its power. Assuming that current and regularly updated photo-ID catalogs include every living and dead member of the population, researchers can make highly precise estimates of population size, adult survival, and calf survival (Pace et al. 2017, Oleson et al. 2020, Pace 2021). Recent modifications in analytical approaches have further increased the precision of population estimates by including additional variables. For example, the ASRG recently commented that NARW mortality estimates should include observed and "cryptic" deaths which are evaluated using photo-IDs (Pace et al. 2021). For these reasons, stock assessment reports ultimately rely on photo-ID data analysis.

The NARW, specifically, is among the most studied large whale species in the world, a credit to scientists who contributed photographs to and curated the NARW photo-ID catalog for decades. The level of effort and degree of rigor in analyses derived from this method is somewhat unique in the marine mammal world and is the basis for much of what is known about the species. It is important to continue expanding this database because of the critically endangered status of the NARW population, recently documented deaths, and current population decline.

4.3.2 Survey Responses About Photo-ID Studies

Several responders indicated they rely on photo-ID methodologies in their studies. As to future work, one responder expressed the need to maintain ongoing aerial photo-ID studies and noted their importance in providing "a comprehensive understanding of right whale residency and movement patterns to inform risk management." One respondent expressed concern about the longevity of the photo-ID database and uncertainty about which organization and/or agency ultimately would fund and curate it.

4.4 Vision-Enhanced Observations—Infrared Cameras and Related Technologies

4.4.1 Overview of Completed or Ongoing Studies

There is growing interest in enhancing or complementing optical camera systems with infrared (IR) sensors to detect whales during low-light conditions. Building on research that began in the 1980s (e.g., Greene and Chase 1987, Cuyler et al. 1992), investigators have explored various types of vision-enhancing devices to monitor marine mammal presence.

For example, Zitterbart et al. (2013) evaluated an automatic, ship-based, thermographic system that scanned continuously for whale blows. Smith et al. (2020) tested the performance of a rotating infrared camera used in conjunction with (unaided) visual and acoustic detectors.

It should be noted that IR sensors, visual surveys, and PAM techniques are all affected differently by various factors and environmental conditions. Often, the weaknesses in one system are another system's strengths. Therefore, using complementary monitoring methods often increases the rate of animal detection (Smith et al. 2020, Smultea et al. 2021).

For more information, see the reviews by Verfuss et al. (2018) and Smultea et al. (2021) on vision-enhancing systems methods and history, limitations, and comparisons with other detection methods such as PAM and visual surveys.

4.4.2 Survey Responses About Vision-Enhanced Observations

One commenter thought it was important to advance night-vision and infrared or other vision-enhancing technologies to improve night-time detections of marine mammals near geophysical surveys and construction sites. The responder suggested using systematic field trials to vet various devices. Another commented that on-site monitoring practices should “be primed to incorporate technological advancements, particularly with respect to visual monitoring that currently relies on vessel-based protected species observers (PSOs)” but did not indicate what specific infrared or ‘night-vision’ devices technologies this might entail. Another responder suggested enhancing thermal systems with artificial intelligence models to autodetect species. The same respondent advocated for the continued development of low-light detection systems and demonstrations of new tools.

4.5 Satellite and Unmanned Aerial System (UAS) Remote Sensing

4.5.1 Overview of Completed or Ongoing Studies

4.5.1.1 Satellites

Satellite and other space-based remote-sensing methods are relatively new to the study of marine mammals and have not yet been widely adopted. This may be due to a lack of funding for satellite bandwidth, data processing issues, the challenges of automating systems to reliably detect images with whales, and/or the relative unreliability of confirming whale sightings over broad geographic areas (e.g., Höschle et al. 2021). Several studies have tried using satellite imagery to detect and count marine mammals, including whales, but the results were mixed (e.g., Abileah 2002). Nonetheless, some studies have been successful. LaRue et al. (2011) and McMahon et al. (2014) used satellite imagery to detect seals and Charry et al. (2021) to detect whales. Cubaynes et al. (2019) and Höschle et al. (2021) visually and spatially analyzed satellite-based (WorldView-3) Very High Resolution (VHR) images to detect baleen whale species, and Fretwell et al. (2014) detected and counted Southern right whales (*Eubalaena australis*) in the Golfo Nuevo, Península Valdés, Argentina with VHR satellite (WorldView2) satellite images. Cubaynes and Fretwell (2022) created a public dataset with 633 annotated whales identified from WorldView-3, WorldView-2, GeoEye-1, and Quickbird-2 satellite images.

With funding and support from the Canadian Space Agency (CSA), researchers from Fisheries and Oceans Canada (DFO) and Transport Canada (TC) announced a plan in January 2021 to develop a real-time, satellite-based detection system to reduce threats to NARW (Hatfield Group 2021). The project hopes to develop “a platform that will detect and monitor NARWs using deep learning models, high-resolution space-based satellite imagery, automation, and geoscience computing.” The work is part of a smartWhales program that seeks innovative solutions (primarily applying Earth Observation Data), that will better monitor and detect NARWs in Canadian waters and predict their movements (smartWhales 2022).

4.5.1.2 Unmanned Aerial Systems

Researchers are also increasingly using UAS, or drones, in cetacean studies worldwide (e.g., Christiansen et al. 2016, Dawson et al. 2017, Burnett et al. 2018). This rapidly emerging technology method uses small-scale, hand-launched UASs to remotely gather images. Researchers use these photos to estimate body measurements and condition metrics (e.g., Body Area Index; Bierlich et al. 2021) and identify marine mammals. Data they collect are also used in behavioral, and disturbance studies. They may also have applications in the Atlantic OSW environment to monitor construction sites. Keller and Willke (2019) are even using UAS to collect physical blow samples.

Transport Canada is also experimenting with long-range (beyond the pilot's line of sight), remotely piloted aircraft systems to detect NARWs in the Gulf of St. Lawrence. They recently conducted trials with the Sea Hunter drone, which flew more than 5,500 km (Transport Canada 2019). However, we note that the U.S. Federal Aviation Administration places some restrictions on long-range UAS flights. UASs have also been used to estimate cetacean abundance. Uncertainties remain about their overall utility for this purpose. For example, in a study of beluga and bowhead whales, Ferguson et al. (2018) found that human observers reported higher density estimates with lower uncertainties when compared to estimates derived from UAV imagery.

4.5.2 Survey Responses About Satellites and UAS Remote Sensing

Few responders commented on satellite imagery as a useful technology to detect whales, perhaps because of the inherent challenges listed above, and/or the fact that technology is still in development with not a lot of information available to evaluate to date. However, one respondent, noted that satellite data could be more cost-effective than even PAM. The same responder emphasized using satellites to monitor seasonal whale distribution and remote-sensing technologies to predict oceanographic and/or prey field changes, coupled with developing predictive models for presence and/or absence that use remotely sensed data.

There were few comments or recommendations on the use of UASs, even though they are being used in multiple studies and locations to gather photo-ID, photogrammetric, and behavioral data. Nonetheless, one respondent indicated that unmanned aerial drones and underwater gliders can collect useful data and are safer instruments for recording animals. The respondent's latter point regarding safety is presumably referring to the inherent risk associated with placing human observers on ships at sea or aloft in aircraft.

Another highlighted the possibility of using Remotely Piloted Aircraft Systems (unmanned aircraft which are piloted from a remote pilot station) (Remotely Piloted Aircraft 2022) as a means to cost-effectively, and with little risk to humans, conduct very large-scale whale surveys.

One survey responder identified a technique to count whales from space (Draper 2019), which informed occurrence forecasts used to mitigate industrial impacts through ship slowdowns and timing of seasonal exclusion areas. Another suggested that artificial intelligence could be used to detect whales from satellite imagery.

4.6 Tagging and Telemetry

4.6.1 Overview of Completed or Ongoing Studies

The use of satellite and radio tagging technologies has come of age in the study of large whales and has grown much in the last two decades. The technology is now commonly used to characterize and provide new information on such things as large whale movements and migrations (e.g., Garrigue et al. 2015; Urbán et al. 2021), habitat use (e.g., Citta et al. 2014, Irvine et al. 2014, Derville et al. 2020), diving (e.g., Mate et al. 2017), feeding (e.g., Wiley et al. 2011, Palacios et al. 2021) and acoustic behavior (Nowacek et al. 2014).

Most tagging systems for large whale species are either implanted, i.e., anchored into the blubber or fascia-muscle interface, or attached short-term with suction cups (e.g., Andrews et al. 2019). Position and other data are typically collected via satellite-mediated feeds during long-term or long-range deployments (NASA 2018) or via very high frequency (VHF) radio signals during short hour to day-long behavioral studies.

Although tagging can be exceedingly useful in advancing understanding of whale movements, ecology, and behavior, some researchers have raised concerns about disturbing animals while affixing tags and health issues associated with invasive tags (e.g., Weller 2008, Moore et al. 2013, Robbins et al. 2013). Disturbing or potentially compromising the health of individuals of a highly depleted population such as the NARW are important factors when weighing the advantages/disadvantages of tagging studies (e.g., Andrews et al. 2019).

4.6.2 Survey Responses About Tagging and Telemetry

NARW radio and satellite tagging technology received only a few comments. One respondent indicated that tagging NARW was needed to "know where they are all the time, where they go when our planes do not see them, and what their migration routes are." Another suggested there is a need to study "fine-scale and/or individual movement patterns within a habitat, which could include satellite tagging during shoulder seasons when groups are transitioning between habitats." Another suggested expanding the Vemco receiver network to increase the range of tagging studies.

Mitigating the impacts of piling noise on baleen whales is one of the biggest challenges for the OSW industry and also "one of the biggest data gaps (and potential showstopper)." Far-field construction noise effect studies require tagging animals, both with short-term acoustic tags and longer-term satellite tags. Satellite tags, especially, provide critical, regional-scale individual movement data in a relatively cost-effective manner. One researcher indicated his program plans to incorporate tagging studies into ongoing research on the physical components of aggregating prey resources and collaborative demographic and health data studies of NARW.

One respondent noted that large, invasive animal tags could adversely affect a whale's health and pointed to miniature acoustic tags being used on multiple marine vertebrate species as being less invasive than some customarily used fully implantable tags. If large whale tags could be miniaturized or otherwise be made safer, they could have more applications in NARW studies.

4.7 Regional Occurrence Monitoring and State Waters or Site-Specific WEA Surveys

4.7.1 Overview of Completed or Ongoing Studies

Large-scale monitoring provides data to estimate abundance, understand species distribution, and assess changes in distribution that occur over a large geographic area or even the animal's entire range. These programs are usually administered and funded by multiple, collaborating organizations and provide high-value, long time-series datasets. They monitor using visual, acoustic, and photographic data collected from vessels and aircraft.

The Atlantic Marine Assessment Program for Protected Species (AMAPPS) is an excellent example of a large-scale, multi-year, collaborative aerial cetacean monitoring study that overlaps with the NARW range. In place since 2010, AMAPPS (e.g., NEFSC-SEFSC 2021, Palka et al. 2017, Palka et al. 2021) provides valuable data on changes and trends in occurrence, distribution, and abundance of cetaceans and other species. The program is conducted primarily by NOAA Fisheries Northeast and Southeast Fisheries

Science Centers, and is collaboratively funded by BOEM, the U.S. Navy, U.S. Fish and Wildlife Service, and NMFS.

These range-wide or regional-scale surveys, conducted every summer, provide the means to assess interannual variability in species abundance and distribution. Data from the surveys are readily available and typically form the basis for annual and semi-annual Stock Assessment Reports (NMFS 2022a). Much of the program's rigor and value is derived from its long temporal data series and standardized survey techniques. One shortcoming, however, is that NARW are observed relatively infrequently, and therefore the sightings and distribution information is limited. In addition, the surveys are limited primarily to summer.

NMFS does administer other efforts specifically targeted at NARW: the North Atlantic Right Whale Sighting Survey (NARWSS) and Right Whale Sighting Advisory System (RWSAS). Performed via aircraft, the primary function of NARWSS is to quantify NARW seasonal distribution and collect photo-ID data. Systematic track lines are flown from New Jersey to Canada. The RWSAS was designed to reduce collisions between ships and the NARW by alerting mariners in real time to a whale's presence. A combination of the RWSAS, U.S. Coast Guard resources, shipboard surveys, and whale watch vessels help establish criteria for designating Dynamic Management Areas aimed at reducing vessel strikes. Other agencies conduct companion surveys in NARW nursery waters off the southeast United States (e.g., Surrey-Marsden et al. 2018, Right Whale Conservation 2022) to quantify calf presence, alert mariners, and reduce vessel collisions on NARW.

NARW sighting information is usually compiled in annual summary reports (e.g., Surrey-Marsden et al. 2018, Khan et al. 2018) and provided to wildlife data repositories such as the OBIS-SEAMAP program (OBIS-SEAMAP Dataset 2022), North Atlantic Right Whale Sightings Database (Sightings Database 2022) and photo-ID databases (Photo and Data Submission 2022).

Many site-specific studies provide baseline distributional data of NARW and other species in offshore WEAs. They typically employ aircraft- and vessel-based visual observations and PAM techniques to evaluate areas for wind energy farms. Waters off North Carolina and Georgia (Rice et al. 2014, Hodge et al. 2015), Virginia (Mallette 2014, Salisbury et al. 2018), Maryland (Bailey et al. 2018), New York (Tetra Tech and LGL 2020, Zoidis et al. 2021), Massachusetts, and Rhode Island (Kraus et al. 2016, Leiter et al. 2017, O'Brien et al. 2021, Quintana-Rizzo et al. 2021) have all been assessed.

4.7.2 Survey Responses About Regional Occurrence Monitoring and State Waters or Site-Specific WEA Surveys

Numerous survey responders noted the importance of large-scale monitoring programs to continually assess NARW spatial-temporal occurrence, habitat use, and risks.

Other responders focused on NARW occurrence assessments at a smaller scale in U.S. mid-Atlantic waters, especially where OSW activities are planned or underway. Another suggested ongoing monitoring is particularly important where NARW "utilize non-traditional foraging and breeding areas."

Many survey respondents emphasized the importance of long-term studies. One summarized this sentiment by commenting "[t]he highest priority is to maintain long-term studies that have the power to detect change in populations and distributions in this area." Another indicated that ongoing and "continued regional monitoring is critical;" and another indicated that multi-agency commitments to long-term monitoring were vital. One responder suggested that future BOEM studies should utilize surveys extending from the SC-NC border to the Great South Channel and fund or encourage more frequent survey efforts (more frequent than AMAPPS, for instance), e.g., about once per month year-round to increase rigor and resolution of marine mammal distribution information. Another suggested year-round monitoring should be conducted in known NARW occurrence areas.

One researcher expressed the need to review the locations and dimensions of systematic surveys to ensure that the current temporal and geographical scales are appropriate (e.g., waters of the U.S. mid-Atlantic states) and that they are streamlined (i.e., only those necessary), efficient, and cost-effective. A NARW monitoring and surveillance working group similarly recommended assessing aerial and vessel surveys to ensure they are efficient and precisely estimate key demographic features (Oleson et al. 2020).

4.8 Environmental Monitoring: Oceanographic, Ecological, and Prey Studies

4.8.1 Overview of Completed or Ongoing Studies

In areas where NARW occur, the underlying ecology, habitat features, and prey behavior greatly influence their movement patterns. Assessing these features is crucial to understanding NARW distribution. Completed studies include Johnson et al. (2011), Kraus et al. (2016), Ji et al. (2017), O'Brien et al. (2021), and Owen et al. (2021)—all of which conducted zooplankton studies in key NARW feeding areas.

Warming waters, however, are causing interannual variability in prey occurrence and distribution (e.g., Pinsky et al 2013, Hare et al. 2016). This variability complicates efforts to quantify the ecosystem features influencing NARW prey distribution. Habitat and prey regime shifts are likely to negatively influence the already vulnerable NARW population (e.g., Greene 2016, Silber et al. 2017, Meyer-Gutbrod et al. 2021), especially when combined with anthropogenic stressors. Studies, including one by the University of Maine (Runge et al. 2023), aim to understand how the long-term variation in plankton distribution influences NARW feeding grounds.

4.8.2 Survey Responses About Environmental Monitoring: Oceanographic, Ecological, and Prey Studies

A relatively large number of responders indicated that prey, habitat use, and ecological studies should be a priority. Several commented on the need for oceanographic modeling to assess the distribution of NARW prey resources, and several noted that such studies become increasingly important as prey distributions are shifting in response to ocean temperature changes. One commenter prioritized studies on how physical oceanographic changes also impact prey fields and result in shifting NARW distribution, especially in seasonal use areas.

One researcher noted that OSW development may change animal distribution on a large scale. Thus, the ecological, physical, and anthropogenic factors that drive habitat selection are fundamental to understanding long-term OSW effects. Therefore, organizations and researchers should support holistic ecosystem-based programs, especially those focused on predictive habitat use. This work likely requires strong collaboration.

One responder recommended using multiple monitoring methods, including prey surveys, to robustly assess the severity of piling disturbance and that such studies need to be concurrent, coordinated, and focused on baleen whales. Another recommended broader-scale (than currently conducted by NOAA) oceanographic monitoring and modeling to assess how stratification mixing and currents may influence zooplankton distribution. A second commenter echoed this, indicating the need for broad-scale zooplankton monitoring—including stratified, random survey designs—and investment in long-term monitoring stations.

Another suggestion was to use site-specific (e.g., near turbines) and regional-scale oceanographic modeling at a relatively high temporal and spatial resolution (e.g., using UASs) to document baseline conditions and assess future impacts.

Another individual commented that "[o]ffshore wind is building entire new ecosystems where turbines insert intertidal habitat in offshore waters. Priorities should be to characterize the organisms that populate turbines, and to define the ecological connections among individual turbines and the bottom-up drivers of this new offshore environment."

One survey responder noted a move toward using dynamic, energetic models with an emphasis on certain demographic groupings. Such models could help focus survey design, tagging efforts, or identify specific parameters to monitor. Similarly, one responder indicated its importance in understanding NARW prey utilization to improve bioenergetic models. Future, critical work recommendations included spatially explicit estimates of NARW prey density and availability throughout the species' range, including interannual variability assessments, and quantifying reproduction costs through extensive, individual body condition surveys (e.g., photogrammetry studies across the range and the year). There are significant unknowns in NARW bioenergetic studies that need resolution, including a) accurate values for basal and field metabolic rates, b) improved measurements of actual prey ingestion rates, and c) reproductive costs (gestation and lactation) and regulation of investment as a function of nutritional status. These assessments would provide data needed to project NARW and prey distribution in response to new oceanographic regimes and anthropogenic climate change. These data should be coupled with spatially explicit estimates of collision and entanglement risk throughout the species' range.

Another respondent called for additional studies on oceanography and habitat characterization as parts of overall study programs, including in the Gulf of St. Lawrence where nearly half of the cataloged right whale population has been documented since 2017. Related to this, one commenter called for coordination and data integration between Canada and the U.S.

4.8.2.1 A note about Environmental DNA analysis

Environmental DNA (eDNA) is a survey tool to detect species' presence, monitor movements, and assess an area's biodiversity. Although uncertainty remains about this technique's sensitivity, recent advancements (Mathieu et al. 2020; Farrell et al. 2022) highlight its potential for monitoring both marine mammals and their prey. One commenter viewed the method as complementary to any ecosystem monitoring strategy, noting that seasonal eDNA analysis on baseline water samples within each OSW area might be easily added to other surveys at a low cost.

4.9 Studies of Stress and Health

4.9.1 Overview of Completed or Ongoing Studies

Numerous studies (e.g., Sheriff et al. 2011, Seltmann et al. 2020) document that natural or human-induced stress affects the health of all kinds of animal taxa (e.g., terrestrial and sea birds, terrestrial mammals). In turn, the adverse health of individual marine mammals can indicate acute or chronic environmental or anthropogenic stressors which may cause general, population-level declines.

There are various forms of individual, marine mammal health assessments (for a review, see Hunt et al. 2013). A common method uses metrics, such as skin condition, general body condition, and scarring, to visually judge the relative health of individual whales. NARWs were one of the first species to receive this visual health assessment through photographs (Pettis et al. 2004) and the technique is now widely used to monitor cetacean health (e.g., Miller et al. 2012, Fearnbach et al. 2019). Recent studies (e.g., Christiansen et al. 2016, Bierlich et al. 2021) employed unmanned vehicles to gather body condition data which is being used in numerous health assessments.

Directly measuring stress by quantifying stress-related hormones can be logistically challenging, but methods to do so have rapidly advanced and diversified (e.g., Lysiak et al. 2018). Assessing stress is also complicated by an organism's habituation to individual or chronic stimuli (e.g., Grissom and Bhatnagar 2009, Rabasa et al. 2015).

Researchers (e.g., Rolland et al. 2017) have analyzed stress hormones in NARWs after exposure to underwater noise, entanglement, and other anthropogenic sources. Possible physiological and pathological responses, even if sub-lethal, are especially concerning in the already depleted NARW population. To advance NARW health monitoring, the 2020 Health Assessment Workshop for North Atlantic Right Whales reviewed current impacts to, and current and prospective health assessments of, the NARW (Fauquier et al. 2020). The workshop sought to summarize the NARW population status and existing health assessments, identify ways to prioritize health data collection, tools and methods to increase the use of health data in monitoring individual and population health, and understand how multiple stressors impact population-level health. To achieve these goals, the workshop recommended continuing to develop the population evaluation tool model and a population-level, state-space model with integrated health metrics. They also promoted collecting more health metrics such as biopsies, photographs, photogrammetric length and width measurements, blow, feces, visual health, and scarring. Finally, they recommended standardizing photogrammetric and visual health data collection methods.

As a follow-up to the workshop, Moore et al. (2021) identified future health assessment needs and encouraged emerging tool development. In particular, Moore et al. (2021) highlighted developing survival models that emphasize reproductive females, continuing work on a NARW population evaluation tool to provide prospective estimates of extinction risk and other demographic characterizations over various time scales; and using baleen whale microbiomes as potential health indicators.

4.9.2 Survey Responses About Studies of Stress and Health

Several survey responders recognized the importance of health assessment monitoring. One commenter, for example, indicated that health assessments are "[s]o often mentioned in impact assessment, [but] so rarely actually studied."

One survey respondent described the importance of studying baleen whale health physiology because their tissue records how they cope in a changing environment. The respondent advocated new biomarker studies (e.g., T3, corticosterone and/or aldosterone in blubber biopsies) and further research and development of respiratory vapor analyses. The respondent stated doing so would advance our understanding of how and/or when these animals respond physiologically, the gradients of stress and existing ecological conditions, and if and how individual animal physiology influences population processes. The responder added that conservation physiology has not existed long enough to be incorporated into management strategies, but the science holds great promise for providing information and decision-making tools.

5 Modeling and Analysis Techniques

5.1 Distribution and/or Spatial Density and Occurrence Modeling

5.1.1 Overview of Completed or Ongoing Studies

Much of the understanding of marine mammal spatiotemporal patterns that are needed to mitigate anthropogenic threats is derived from occurrence and spatial density and/or distribution models. The literature on these analyses is too broad to reasonably summarize her, but studies by Best et al. (2012), Forney et al. (2012), Roberts et al. (2016), and Wedding et al. (2016) are illustrative examples, some with applications to the NARW.

Spatial density models provide important information to assess the impacts of OSW energy and other maritime development. For example, they can help plan industry activity in a way that minimizes marine mammal exposure to risk (Pendleton et al. 2020). Large-scale, spatial surface density models for large whale species which cover regions (e.g., Dransfield et al. 2014) or entire coastlines (e.g., Forney et al. 2012, Roberts et al. 2016, Roberts et al. 2017), have been used explicitly for marine mammal risk assessments (e.g., Redfern et al. 2013, Dransfield et al. 2014).

Shipboard visual surveys, aircraft-based line-transect visual surveys, and stationary PAM are primary data sources for these cetacean occurrence and density models. Substantial amounts of historic and modern survey and acoustic data for NARW already exist and are archived in various data repositories (e.g., NOAA's National Centers for Environmental Information, NOAA Fisheries' Northeast and Southwest Fisheries Science Centers, NOAA's Cetacean and Sound program, and the Marine Geospatial Ecology Lab, Duke University, among other locations (NOAA and NCEI 2017, https://cetsound.noaa.gov/sound-index). Numerous U.S. institutions (e.g., NOAA Fisheries' Northeast and Southwest Fisheries Science Centers, the Marine Geospatial Ecology Lab, Duke University, among others) routinely use these data in modeling exercises.

5.1.2 Survey Responses About Distribution and/or Spatial Density and Occurrence Modeling

One respondent indicated that density models are important because they are "used throughout industry and government agencies for purposes such as preparation of environmental impact statements, incidental harassment authorizations, changes to fishery rules, assessment of [the] risk of entanglement and vessel collision, etc."

Another commenter emphasized the importance of continually updating spatial occurrence and density models as new data are acquired. This requires a long-term commitment to additional data collection and model refinement. For example, the commenter noted that hind-casts could be used to validate and further "educate" in-use models.

A principal need noted by one commenter was providing visual and acoustic data-based model results as real-time density maps and short-medium term forecasts, especially those generated from contemporaneous observations of whales and oceanographic conditions. In contrast to long-term forecasts, real-time or short-term predictions would powerfully allow agencies, regulators, operators, and others to quickly adjust operations and mitigate immediate impacts.

One respondent noted that existing, substantive datasets can support real-time results, short-term forecasting models, and risk assessments with increasing precision and decreasing uncertainty. This would require a greater amount of and higher resolution oceanographic data, more data analysts, and more efficient data streams from data collectors. The same commenter expressed the need to either free up, or provide funding for, additional analysts able to generate timely (and retrospective) data synthesis and reports related to OSW energy development.

Related to this, another responder highlighted the need to recruit skilled coders to address the long-term challenges related to data “collection, integration, real-time monitoring, cloud storage and query, analysis, reporting, and long-term archiving.”

5.2 Predictive Modeling

5.2.1 Overview of Completed or Ongoing Studies

Predictive occurrence and density maps for marine organisms (e.g., Hamazaki 2002, Keller et al. 2012, Becker et al. 2014, Miller et al. 2013, Redfern et al. 2017, Fiedler et al. 2018) are a valuable tool for marine species management (e.g., Redfern et al. 2019). The approach constructs models by combining extensive, pre-existing marine mammal occurrence datasets with oceanographic, biological, and physiographic features. Given the size and geographic extent of many datasets, generating these relative density maps takes significant computing capacity and resources.

These models can potentially predict the location and density of marine mammal populations, even in changing environments. Therefore, they are a powerful tool to help plan and implement mitigation measures (e.g., Pirotta et al. 2018b, Abrahms et al. 2019). See Ross et al. (2021) for a long-range forecast habitat-use model developed specifically for NARW.

5.2.2 Survey Responses About Predictive Modeling

Several respondents emphasized using existing and newly acquired data to develop predictive models about where and when NARW occur and in what densities. Several noted, for example, that OSW mitigation measures could be more effectively planned if whale occurrence was anticipated.

One indicated the need for forecast modeling that fully integrates large-scale ecosystem components. It is possible, for example, to model cascading effects from the North Atlantic Oscillation and other large-scale phenomena on local scales. Another highlighted the need to develop right whale forecasting models under different climate change scenarios.

One indicated that recent work by Owen et al. (2021), who used dimethyl sulfide (DMS), a by-product of zooplankton feeding, can be used to determine possible locations for NARW feeding aggregations. Work is also underway to determine whether this indicator of feeding aggregations can be detected remotely.

5.3 Disturbance and Cumulative Impact Modeling

5.3.1 Overview of Completed or Ongoing Studies

Comprehensively assessing risks to marine mammal physiology, behavior, and long-term population status is complicated (Pirotta et al. 2018a). Modeling of disturbance is helping to fill that gap, and much modeling work is underway to predict possible responses to disturbance and other stressors.

Models are used to estimate exposure risk and consequences of stress on individual marine mammals and populations (e.g., NRC 2005, Pirotta et al. 2018). Some models focus on the effects of single or multiple stressors; a others simulate how animals interact with their environments (e.g., Ellison et al. 2011, Frankel et al. 2015). Various equation-based models can provide estimates of and evaluate relationships between parameters to inform those assessments.

Two of the various models in use today include the Population Consequences of Disturbance (PCoD) model (for reviews, see Booth et al. 2020, Keen et al. 2021) and the Population Consequences of Acoustic Disturbance (PCAD) framework (NRC 2005). An interim PCoD model exists for use in data-poor situations (King et al. 2015).

Effects from multiple anthropogenic stressors can have additive impacts on living marine resources and may threaten ecosystem or population health and function; thus, studies also attempt to model the cumulative impact of multiple environmental and anthropogenic stressors (Population Consequences of Multiple Stressors (PCoMS) (e.g., NAS 2017, Pirotta et al. 2022). Modeling multiple stressor effects is an expanding field that seeks to understand and predict interactions between stressors. These and other models are summarized in NRC (2005), NAS (2017), Southall et al. (2021), and Appendix D.

Estimating the effect of multiple stressors can be analytically challenging (e.g., NAS 2017, Orr et al. 2021) and the effects may not always be additive (Jackson et al. 2021). To predict these combined effects, evaluations must make assumptions about the severity of harm resulting from human activities and natural phenomena. Assumptions are especially needed in data-poor scenarios. However, incorrect underlying assumptions can introduce biases into the models (Pirotta et al. 2022). Nonetheless, PCoMS and other models are in common use. In the case of the NARW, cumulative impact studies are underway, including a four-year study initiated in 2020 and led by the Sea Mammal Research Unit and Duke University, that includes a NARW case study (Tyack 2020, Duke University 2021). Dr. Richard Pace from NOAA Fisheries, Northeast Fisheries Science Center is leading a collaboration to develop a population viability analysis that will allow NMFS to characterize the North Atlantic right whale extinction risk, considering current and future threats, and will allow inquiry into how much improvement to present-day mortality and reproductive rates is needed to improve population trajectories. These modeling initiatives seek to assess the interplay of multiple stressors on the NARW population, and especially their relationship with ongoing, direct impacts such as fishing gear entanglement, vessel strikes, reductions in prey availability or quantity, and OSW energy and other human activities.

It is important to note the limitations of models. They all have some level of uncertainty that needs to be assessed and, if possible, quantified. A model's underlying assumptions will affect its outcomes; therefore, assumptions need to be chosen carefully, adequately explained, and examined in light of the model's conclusions. Generally speaking, to identify population-level responses, the "effect size" (or the magnitude of the relationships between two variables) needs to be large. Ideally, the models themselves should be routinely evaluated and updated as new data become available.

Based on these models and other data, decision-making frameworks to manage disturbance of cetaceans at the population level are being developed and can be applied to NARW and OSW studies (e.g., Pirotta et al. 2018a, Booth et al. 2020, Wilson et al. 2020).

5.3.2 Survey Responses About Impact Modeling

As indicated by an expanding body of literature, the direction of agency funding, and responses to our survey, interest in cumulative impact modeling is growing rapidly. Many survey responders are involved in ongoing modeling efforts and/or commented on their utility with regard to OSW (and other) activities.

One responder indicated that sub-lethal stressor modeling exercises, PCoD for example, were "much needed" but also noted that they are "very hard to do." Another suggested a review of recent literature would help determine parameters required to undertake PCoD modeling and identify which data are necessary to refine these models in NARW-focused work.

Another survey respondent is developing a PCoMS model that can test alternative disturbance scenarios. The model will quantify the energetic incomes and expenditures of female right whales over a one-year cycle in the context of offshore wind-related disturbance. Using an accompanying software interface, the model will generate visual and graphical summaries to support decision-making.

Another commenter favored the use of the PCoMS framework, indicating that it "highlights the value of long-term individual animal health data needs" and noted that "clearly this is [a] topic area worth funding for priority species like NARW." Related to this, one responder indicated that current, cumulative modeling exercises would address prey limitations, in addition to entanglement, vessel collision, and noise exposure.

Several respondents noted the uncertainties in assumptions made, values used, variables being evaluated, and other factors when modeling the long-term effects of anthropogenic stressors. One noted, for example, that there are challenges associated with models but "they are all we've got."

5.4 Risk Assessments

5.4.1 Overview of Completed or Ongoing Studies

Many researchers, industries, and organizations create risk assessments by overlaying spatiotemporal representations of human activities with marine mammal densities. Risk assessments are typically shown by "heat maps," model-generated values representing locations and extents of overlap. These outputs can help guide management strategies that are tailored to computed risk values and even account for environmental variability (Redfern et al. 2019). Using this approach managers can also evaluate the effectiveness of risk-reduction measures.

Examples of model-generated risk assessments include those for vessel strikes (e.g., Fonnesbeck et al. 2008, Redfern et al. 2013, Rockwood et al. 2018, Shearer et al. 2019) and entanglement in commercial fishing gear (NMFS 2020a, DFO 2019, Macks 2019, Hines et al. 2020). Barkaszi et al. (2021) provided estimates of risk from vessel traffic in Atlantic OSW WEA.

5.4.2 Survey Responses About Risk Assessments

Several survey respondents emphasized the importance of risk models because they influence WEA management. For example, one survey responder suggested a focus on "acute effects (specifically spatial changes in fishing effort, vessel strike risk along supply routes) and far-field noise effects from the construction, with a focus on quantifying time-area risk likelihood [and] identifying potential solutions. This would naturally include projects testing cost-effective, reliable real-time monitoring and localization, the use of novel techniques to improve species detection, methods to reduce source levels and propagation of piling noise, testing methods to reduce strike risk and fishery interactions."

5.5 Mining Existing Datasets

5.5.1 Overview of Completed or Ongoing Studies

While not a technology-driven technique or survey type, mining existing datasets is a cost-effective way to use information on whale occurrence and a means to study or minimize impacts. This is especially relevant to the NARW because it is among the most studied marine mammal species in the world. As noted previously, there is a wealth of data collected by regional and site-specific surveys (e.g., Wall et al. 2021) and their datasets are housed and analyzed by various programs, including, for example, NOAA and NCEI 2017, CetSound (https://cetsound.noaa.gov/sound-index), and OBIS-SEAMAP. Also, proprietary data are routinely collected by industry operators (including OSW-related operators) and academic researchers and in many circumstances are not made publicly available and are therefore not accessible for the types of analysis being discussed here. But in some cases, funders are requiring data be made public via stipulations in contracts and grants. Classified military data are not available, but some data collected by the U.S. Navy are available. Mining these datasets could help address specific questions regarding NARW seasonal occurrence, distribution, and changes in distribution. These existing data might also help design future, more efficient monitoring plans (Oleson et al. 2020).

5.5.2 Survey Responses About Mining Existing Datasets

As noted by one survey responder, a wealth of data collected throughout the range of the NARW is not fully used. At least one commenter indicated that some NARW sightings data are not yet in these large-scale data repositories and including them would benefit modeling exercises and other analyses.

It is important not only to collect but to efficiently use large marine mammal monitoring, sightings, and oceanographic datasets. To that effect, one survey responder emphasized establishing cloud integrations, developing dashboards for managers, having real-time project oversight, and creating management tools that track large data inflows. Compiling new datasets from different companies and scientific groups would also help advance marine mammal science, but funding to pursue systematic data sharing and periodic reporting is lacking. One survey responder recommended funding efforts that specifically compile and synthesize regional information from reports and papers on an ongoing basis.

Several responders noted the importance of data sharing and the need to enhance NARW detection data archiving and curation. One responder indicated that its programs are making contributions, but greater opportunities for collaboration would help leverage resources for common interests and shared objectives and make data-sharing efforts more effective.

6 Detecting and Assessing Biological Impacts from OSW Energy Development and Other Human Activities

6.1 Overview of Completed or Ongoing Studies

Vessel strikes and commercial fishing gear entanglement are serious threats to the NARW population. These impacts have direct and profound long-term consequences on population growth trajectories. However, other threats exist.

Studies have noted that indirect threats–such as loud underwater noise, pollutants, and habitat destruction–negatively influence an individual's behavior or health and eventually impact the entire population (e.g., NRC 2003, Thomas et al. 2015). Research (e.g., Parks et al. 2011, Gomez et al. 2016) has quantified the behavioral changes in marine mammals following exposure to loud noises. Other studies attempted to quantify parameters, such as air quality, noise, and sediment suspension during OSW construction (Elliot et al. 2017, Boatman 2019).

However, the long-term and population-level impacts from loud noises and other sources are still largely unknown (e.g., Erbe et al. 2019, Pirotta et al. 2018a, Kraus et al. 2019) and are rarely quantified. In addition, the biological consequences of cumulative impacts from multiple sources are difficult to parameterize (NAS 2017, Moore et al. 2021). Simply put, it is not easy to quantify the long-term biological consequences arising from exposure to various human activities.

High-resolution geophysical surveys for site characterization and assessment, pile driving during platform construction, operating turbines, and vessel operations at OSW energy sites introduce sound into the water column (e.g., NRC 2003). Among these, pile driving typically produces sounds with the highest amplitude (Amaral et al. 2020).

The history and literature quantifying the impacts on marine life from seismic (air gun) and geophysical survey-associated sounds are too broad to summarize in this report. However, recent work on sound emissions from pile-driving activities is worthy of consideration here.

Several studies have directly measured or estimated the sound levels associated with pile driving at numerous sites, (e.g., Bailey et al. 2010, Dahl et al. 2015, Guan et al. 2022), including in or near WEAs on the U.S. eastern seaboard (e.g., Halvorsen et al. 2018, Tripathy et al. 2018, Amaral et al. 2020b, Heaney et al. 2020). In contrast, Han and Choi (2022), Heaney et al. (2020), Lin et al. (2019), and BOEM (2018) used simulations and modeling studies, respectively, to determine sound levels from pile driving. Related studies by Sigray and Andersson (2011) and Tougaard et al. (2020) quantified or modeled underwater sound levels emitted by operating wind turbines.

While sound levels from OSW-related activities have been quantified or modeled, their impact on, and the corresponding response by, marine mammals is not well studied (Stöber and Thomsen 2021). To date, most systematic work on marine mammal responses was done in European OSW windfarm sites and focused on species common to those waters, primarily harbor porpoises (*Phocoena phocoena*) and several pinniped species (e.g., Scheidat et al., 2011, Brandt et al. 2016). There are several ongoing, industry-funded studies assessing how marine mammals use the waters around North American OSW sites and the impact of construction and operation at those sites (ECO-PAM project 2022, Stony Brook University 2022, NYSERDA 2021a, NYSERDA 2021b, NYSERDA 2021c, Stoker and Pretyman 2020).

Several studies summarize harbor porpoise responses to OSW activities (e.g., Brandt et al. 2016, Brandt et al. 2018, Verfuss et al. 2016), but their results do not always agree. For example, Teilmann and Carstensen (2012) documented harbor porpoises showing displacement, both short-term (1–2 days) displacement and longer-term (several weeks) changes in behavior or distribution near sites with pile driving and increased vessel activity. In contrast, a study of German North Sea wind farm sites by Brandt et al. (2016) concluded that harbor porpoise populations were not negatively affected by pile-driving activities in the long-term.

As for assessing NARW responses (changes in occurrence and distribution, for example), recent work used (preliminary) power analyses to determine if existing aerial survey effort is sufficient to detect displacement of marine mammals during wind energy construction (Scott-Hayward et al. 2021). These authors concluded that the power to detect a change within a WEA impact area is high, but they also noted that additional (aircraft) surveys are needed to detect a redistribution of whales. They also indicated that additional power analyses could be used, for example, to determine the survey effort required to have high power to detect (1) changes occurring in locations surrounding the impact area, (2) smaller than 90% displacement effects, and (3) displacement of individual species.

6.2 Survey Responses About Detecting and Assessing Biological Impacts from OSW Energy Development and Other Human Activities

Several survey respondents indicated the need to reduce known industrial impacts on NARW from wind energy development and the importance of reducing known impacts from other activities, such as commercial fishing and shipping. A number of respondents commented that it is challenging to separate and measure the biological effects of industry activities from environmental influences on whale distribution, health, and behavior. It is especially difficult to quantify effects at population levels.

One commenter suggested that to more fully assess effects, sites at regional or range-wide scales (similar to the AMAPPS program), single, selected or multiple state waters sites, and specific WEA sites should be monitored before, during, and after construction. The latter would be particularly important to better understand NARW distributional and behavioral changes at WEA scales.

One responder recommended using Before-After-Gradient (BAG) surveys when studying noise effects on baleen whales with PAM technology. Given the uncertainty in the spatial scale of whale response, and thus, difficulty in defining control areas, the results of BAG studies could indicate appropriate spatial scales for future monitoring. The spatial and temporal variability of whale occurrence and low density makes it difficult to understand if and how their distributions change in response to industrial activities or environmental changes. Power analyses can provide information on how effective different methods may be at discerning distributional changes and be used to select the most appropriate monitoring techniques and scales for a given area. However, the same responder noted that intensive sampling is likely required for even moderate power.

Another commenter indicated that, in regard to aerial surveys, “[w]e have the statistical power to detect displacement from a construction site but require more surveys to differentiate the effects of construction from climate-related changes.” The responder also noted that ongoing surveys are needed to understand mechanisms that affect distribution and abundance patterns. In this same regard, one noted that aerial survey coverage within WEAs and the broader region should be on sufficiently large spatial and temporal scales to detect changes in whale presence and foraging locations and identify if the changes are a result of OSW or other factors. Several commenters indicated that aerial surveys should be combined with PAM because the weaknesses and strengths of these data types complement each other, by capturing PAM data on visually cryptic individuals and capturing visual data on acoustically cryptic individuals.

7 Impact Mitigation

7.1 Mitigation

One principal concern of OSW development is how loud underwater noise from pile driving affects marine organisms. Researchers and industry continually seek methods to reduce sound levels. Adopting quieter foundation types (e.g., gravity-based foundations) and incorporating noise abatement technologies to reduce and, ideally, eliminate the noise footprint outside of the offshore wind construction area can help address this impact.

Noise abatement techniques, in use or in development, include bubble curtains or physical barriers (e.g., cofferdams, noodle nets, hydro sound dampers, Helmholtz resonators) to reduce or attenuate sound generated during impact pile driving (for reviews, see Verfuss et al. 2016, Bellmann et al. 2017, Verfuss et al. 2019, Bellman et al. 2020). BOEM and NMFS require various underwater noise reduction measures during OSW turbine construction and operations, including bubble curtains.

Several studies have assessed the effectiveness of bubble curtains at reducing underwater, pile-driving noise (e.g., Lucke et al. 2011, Nehls et al. 2016, Dähne et al. 2017). For a specific study conducted at a Virginia WEA during monopile installation, see Amaral et al. (2020a). However, CSA (2014) reported that no one type of quieting technology solution exists for all locations. This is especially true of ground-borne sound transmission because it is determined by site-specific features, such as water depth and substrate type. Consequently, each project site requires its own analyses to determine the most effective and suitable noise reduction methods.

Studies indicate that noise can also be reduced during wind farm operational phases. For example, using direct-drive technologies, instead of gearboxes, reduces noise (Stöber and Thomsen 2021).

The timing of OSW activities is also used to reduce noise impacts on marine mammals by, for example, restricting OSW construction during seasons of high mammal presence. Engaging in wind farm construction activities when underwater sound transmission is low (due to seasonal differences in water temperature and salinity) has been proposed to reduce sound levels received by marine mammals (Lin et al. 2019, Amaral et al. 2020). In addition, projects such as the Whale Alert System aim to reduce the number NARW and other marine mammals exposed to vessel traffic in wind energy and other areas by providing locations of recent whale sightings to mariners, increasing the chance that mariners can avoid them.

7.2 Effectiveness of Mitigation Measures

Broadly speaking, once implemented, conservation measures are not often evaluated for their effectiveness in achieving intended goals (e.g., Selig and Bruno 2010). Likewise, scant information exists on attempts to assess the effectiveness of measures designed and implemented to reduce the impacts of OSW activities on marine mammals.

For example, it is possible to quantify the intensity of noise or endeavor to reduce its intensity or duration. But it is difficult to determine the long-term biological effects of noise exposure, or how effects may have differed without noise mitigation measures. As noted earlier, the population-level effects from disturbance, such as loud underwater noise, remain largely unknown. To date, there are no known studies aimed at determining if OSW mitigation measures have achieved their intended goals of reducing, for example, disturbance, serious injuries, and other long-term biological or population-level impacts. Moreover, metrics to quantify impacts–changes in distribution or stress levels before and after exposure to a stressor, for example–are rarely, if ever, identified or established a *priori*. Baseline occurrence and distribution data are being collected in various areas; however, with some exceptions, there appears to be little effort toward identifying ways to quantify what a response to an impact might look like or if a mitigation measure might have reduced that impact.

Given the species' vulnerable status, it is critical that action be taken from the start to prevent noise impacts which could further stress the species and impair its recovery. For this reason, having strong noise prevention measures in place as monitoring is conducted can help explore the impacts of even the reduced noise footprint on species in a more precautionary manner.

7.3 Survey Responses About Mitigation

An absence of studies directed at determining the effectiveness of OSW-associated mitigation measures was reflected in relatively few survey comments on the subject; one survey respondent commented on their absence. Another respondent, in referring, presumably, to reducing lethal vessel strikes and fishing gear entanglements said "[m]itigation measures that are young or imminent are challenging because their effects are yet to be observed and could require long time periods (e.g., 10+ years) to understand." Another responder discussed tools to reduce vessel strikes, encouraging "sighting sharing across tools and tool flexibility (i.e., multiple uses use a variety of tools, [as] we will never have one tool all will use)" and "continuing to advance connectivity across multiple data collection and sighting sharing tools."

Nonetheless, commenters indicated that it is very important for BOEM to have an iterative process in place to evaluate the effectiveness of mitigation and monitoring measures. They encouraged the agency to develop objective criteria to assess the effectiveness of these measures and evaluate their effectiveness on a regular (e.g., annual) basis. They further noted that protective measures should be updated as necessary, and the changes incorporated into industrial project requirements.

As discussed previously, emerging disturbance and cumulative effect models are being developed in an attempt to assess mitigation measure effectiveness on time-area closures.

Relatively few responders identified new, emerging, or next-generation technologies that could be applied to NARW monitoring or mitigation measures. That is, instead, most discussed the continued or increased use, or refinement, of existing approaches and methodologies. However, one commenter indicated that because operators can employ noise-reducing technology during pile driving, developers should use a combination of near- and far-field noise abatement technologies proven to reduce noise levels by 15 dB in Europe (Bellman et al. 2020) and should aim for a 15–25 dB reduction in the U.S. The same responder expressed concern that operational sound levels could displace right whales from key habitats and erode habitat quality, suggesting "measures to reduce operational noise, including requiring direct-drive turbines and other engineering solutions to decouple the vibrations generated by the turbine from tower and foundation" should be required.

8 Considerations for Future Actions

Based on a canvass of the NARW research and OSW communities and this report's literature synthesis, summary conclusions and possible directions for future research are provided. Several courses might be pursued, as noted below.

8.1 General Comments

While OSW energy development may negatively impact NARW, some survey respondents expressed the opinion that those effects would likely be small compared to incidents of fishing gear entanglement or vessel strikes, which can severely injure or kill marine mammals.

For example, in response to a question about where BOEM should devote future funding, one responder indicated " . . . highest priorities should focus on industries that are causing mortalities of NARW, i.e., fishing, and funding both new fishing technologies to reduce entanglement and implementing vessel tracking and speed rules for fishing and commercial cargo vessels. Do not expend all your energy on the wind industry when there are already known impacts from other industries." Another commented that " . . . the intense focus on wind farms is a bit misguided, and very welcomed by the fishing industry to take the heat off them. Without [a] very substantial reduction in fishery-related mortality, the species is in a death spiral." Another indicated that "[t]here has to [be] significant SI/M [serious injury/mortality] reductions achieved with NARWs before additional large-scale harassment is brought on them."

However, overall, most commenters more directly addressed questions in the survey, namely, concerns about potential direct and indirect impacts from OSW activities. For example, in regard to OSW mitigation practices, one responder indicated that both habitat displacement and secondary entanglement resulting from the extensive cable infrastructure are concerns. The responder noted that "any entanglement risk, however small, must be mitigated at the outset of planning floating offshore wind development, and particularly in right whale habitat" and that BOEM should require developers to monitor and remove any marine debris ensnared on the cables on a regular basis until the true level of risk is determined by empirical data. Also noted was that "reducing the speed of all offshore wind vessels to ten knots or less [is] essential to adequately reducing [the] risk of serious injury and mortality to right whales and other large whale species."

Another commenter indicated "I highly recommend that BOEM consider working with NMFS to develop offset mitigation in place of some of the direct mitigation for wind farm development. I realize that the MMPA does not lend itself well to that, and I cannot think of a marine mammal precedent, but that approach is taken all the time with terrestrial animals and habitats. For right whales, there is a clear path–rather than spending millions of dollars flying planes around while you build a wind farm, you could spend millions of dollars on ropeless gear for fisheries or further research into means to reduce entanglement and vessel collisions." Another indicated that "my expectation is that wind energy is a minor stressor for NARW. [The] critical issue is how does its effect interact with other stressors."

While some commenters indicated that impacts from OSW activities might be small relative to serious injury resulting from activities, such as commercial fishing and shipping, Federal agencies are required under U.S. law to mitigate impacts to, and promote the recovery of, endangered species.

Several organizations have developed specific recommendations to minimize and mitigate impacts to right whales during offshore wind (Natural Resources Defense Council 2022).

8.2 Passive Acoustic Monitoring

Responders strongly supported expanding PAM by deploying more sensors particularly to fill data gaps. Several commented on the need to better incorporate PAM data from multiple sensors, locations, and studies during data processing to enhance the overall utility of multiple studies. They also suggested ways to improve PAM by enhancing processing and analytical speeds and hiring more analysts. There was also an interest in improving infrastructure to make PAM data available in real time to support decision-making frameworks.

8.3 Vision-Enhanced Observations—Infrared Cameras and Related Technologies

Some promising work has used infrared and related vision-enhancing devices in some contexts, e.g., mammal detections from stationary platforms, geophysical survey vessels, etc. However, there are some limitations and uncertainties in using these devices for these purposes and the technology is rapidly evolving. Therefore, additional field trials and further exploration on the use of these devices as approaches to verify marine mammal presence and relatively near-field monitoring at construction sites and during geophysical surveys appear warranted.

8.4 Satellite and UAS Remote Sensing

Although it appears that challenges remain in remote detection (e.g., use of satellite and drone imagery), U.S. agencies and the research community would be well-served to track and review the results of trials being conducted by Canadian agencies on long-range, air-borne gliders as a safe and cost-effective means to survey for whale presence in large areas (assuming data processing and automated whale detection challenges can be addressed). These approaches have the potential to report whale occurrences in real time.

8.5 Range-Wide or Regional Occurrence Monitoring and State Waters or WEA Surveys

Overwhelmingly, researchers promoted commitments to long-term monitoring to detect and understand changes in distribution, habitat use, health, and other biological features resulting from industrial activity and to reduce future risk. Several identified the need for additional data gathering and monitoring in areas such as U.S. mid-Atlantic waters, where data on seasonal occurrence, abundance, and residency times are relatively few and potential impacts are less known.

Respondents also indicated the value in coupling detailed, long-term monitoring surveys over one or two WEAs with coarser scale surveys. The need for long-term monitoring of prey resources was also stressed. This integration could better detect changes in NARW habitat use and help separate OSW and other industry impacts from those caused by interannual or ongoing environmental variability.

8.6 Studies of Stress and Health

Assessing individual (primarily) and population health, and as a function of stress levels, are rapidly growing areas. Several commenters indicated health assessments should be highlighted to a greater extent in management practices. Advances in remotely piloted drones are a means to address individual health through photogrammetry and in areas such as blow collection sampling and standardized visual inspections are aiding health assessments (e.g., Fauquier et al. 2020). The importance of prey availability and changes in prey availability, as well as understanding of (changing) oceanic processes, were also highlighted numerous times as related to population health assessments.

8.7 Distribution and/or Spatial Density and Occurrence Modeling

Occurrence and density modeling is significantly advancing, and there are numerous data sources to populate models. However, some responders noted that while additional PAM and visual sighting data exist, not all are currently being used. To maximize their utility, models should be continually updated with new data and refined. Data flows are likely sufficient to do real-time modeling but the number of full-time analysts to do the work is often insufficient.

8.8 Predictive Modeling

Forecast modeling of NARW occurrence and densities was an area of interest for several survey respondents. It appears there is much potential in predictive habitat-use modeling, especially as it pertains to anticipating NARW occurrences and densities and planning appropriate mitigation measures. Interest was expressed in enhancing mechanistic forecast models, to help better understand cascading effects, by integrating large and regional-scale ecosystem features. Promising work appears to lie in an ability to predict NARW feeding aggregations using detections of zooplankton by-products (i.e., DMS).

8.9 Impact and Disturbance Modeling

Judging by the levels of activity in the recent literature, agency funding levels, and responses to requests for input to this report, the field appears wholly committed to the rapidly growing area of modeling as a means to assess impacts from individual and multiple stressors. Several responders noted, and the literature reflects, the inherent challenges in parameterizing these models: modeling exercises (such as PCoD) are needed, but they are “hard to do,” one noted. Nonetheless, advances in impact modeling are substantial and several already funded studies should be turning out results in the next few years. Provisions to continually refine such models as new data are acquired should be an ongoing goal.

8.10 Collaboration and Data Sharing

There is abundant data for previous years on the NARW, but not all are publicly available. Ideally, proprietary data collected by industry and research institutes, and datasets curated by BOEM or NMFS would routinely be made available for analysis.

Ways to overcome this old, data-sharing hurdle are not always clear. Perhaps making data more generally available could be a condition of all federally provided permits and authorizations. Regardless, enhancing existing or creating new central repositories (Trice et al. 2021, Wall et al. 2021) that create a means for easier, inter-project collaboration should be encouraged.

Responders expressed the need for improved coordination, collaboration, and data sharing between agencies, between Canada and the U.S., and with other groups currently working on identifying research priorities (e.g., RWSC, New York State Energy Research and Development Authority).

8.11 Detecting and Assessing Biological Impacts from OSW Energy Development and Other Human Activities

Although determining ways to assess the effectiveness of existing mitigation measures—i.e., how is it known that mitigation measures are working as intended?—was a principal goal of this review, most survey responders did not directly address how this might be accomplished. This may be an area for separate study and likely include establishing criteria, using power analyses to assess the effectiveness of existing approaches, long-term planning and ongoing assessments that focus on the most cost-effective and efficient means to reduce potential threats, and a de-emphasis on those that do not meet these or other criteria.

8.12 Impact Mitigation—Reducing Loud Noise Sources

Studies of noise-reducing technologies and approaches received relatively little emphasis from responders. However, some discussed recent technological advances in quieting methods and the need to incorporate them in OSW energy work. Because loud sound sources from OSW activities are a principal concern, this is an area where additional studies would be fruitful. Perhaps this is an area of research interest where BOEM could canvass OSW energy companies, maritime engineers, and others about ways to more fully develop and institute emerging quieting technologies.

8.13 Economic Studies

One survey respondent recommended conducting a "serious cost-benefit analyses to say that the development of offshore wind trumps low return fisheries and those should be closed to allow for harassment takes to be used by wind development . . . ."

8.14 Long-Range Planning

OSW will have an important role in meeting the nation's energy needs. The potential is just being realized: numerous wind farms in U.S. offshore waters are either online (e.g., Block Island Wind Farm in State waters and Coastal Virginia Offshore Wind Project in Federal waters), in planning and/or permitting stages, or will be completed in the coming decades. But their rapid development comes with environmental challenges.

There is an opportunity to implement intermediate and long-term (for 1–10 years) research, budgetary, and regulatory plans to mitigate these environmental effects. To help initiate such planning, BOEM and NMFS recently signed a Memorandum of Understanding to collaboratively work on OSW planning and development (Spinrad and Lefton 2022). To this end, BOEM and NMFS have committed to implementing a North Atlantic Right Whale and Offshore Wind Strategy to protect and to promote the recovery of NARWs and responsibly develop OSW. These agencies, in conjunction with others (e.g., Department of Energy), can and should engage in systematic and thoughtful planning.

Mid- and long-range research planning should consider studies that most directly and cost-effectively provide OSW authorizing and regulatory agencies the tools to ensure wind farms are developed with minimal biological disruption and adverse consequences. Costly solutions that effectively protect the species should also be considered, though perhaps de-emphasized. In addition, agreed metrics should be identified to quantify the actual biological impacts, and the extent to which they arise from OSW and other activities, especially at the population level. Metrics should also be established for understanding if and to what extent mitigation measures are accomplishing what they were intended to accomplish;

namely, a reduction in detectable negative biological consequences of exposure to anthropogenic activities.

Multiple agencies should collaboratively plan and perform these studies and they should seek to connect the entire NARW range. The studies should continuously yield short- and intermediate-term results and provide a means to adapt planning and funding schemes. Plans should flexibly accommodate recent advances and, when possible, incorporate emerging technologies.

Additionally, given the precarious nature of the species, proactive protective measures–particularly in relation to noise and vessel strike threats–must be prioritized for use as the industry scales up.

9 Conclusions

This report identified a broad suite of ongoing and planned research activities to monitor NARW distribution, health, habitats, and assess the impacts of OSW activity by canvassing the NARW research community, environmental groups, and OSW industry representatives.

Recent literature, survey-taker responses, and the products of various workshops and workgroups all reflect the current emphasis on developing or improving upon existing disturbance and cumulative impact modeling methods. Studies that involve disturbance modeling to assess OSW activities' impacts are currently funded, planned, or underway. Though useful in estimating the influences of maritime industrial activities, these studies will encounter challenges of adequately parameterizing variables and, in some cases, accessing sufficient data to fully assess all variables under study.

Surface density models remain a standard tool to assess possible risks from overlapping whale distribution and maritime activities. Advances toward the real-time generation of surface density and habitat-based risk models show promise toward expressing the timing and geographic extent of exposure to noise and other by-products of OSW activities.

Most survey responders indicated that they are involved in PAM studies and aircraft surveys. PAM technologies–especially where sensor arrays are networked–are more cost-effective when compared to aerial surveys for use in to determining whale presence around tightly constrained areas (e.g., near a seismic survey or specified construction location) as well as long-term changes in whale distribution on broad geographic scales. However, aircraft surveys remain important in providing information on site-specific NARW occurrence, distribution, and behavior, and complement PAM activities by increasing the changes of detecting non-vocalizing individuals. In both cases, investment in long-term data collection will be necessary to elucidate longer-term effects of offshore wind development. These methodologies would benefit from assessing the minimum number and most cost-effective spatial distribution of passive acoustic monitoring assets and aerial surveys needed to determine the actual effects of OSW activities (if that is the goal).

Individual whale health assessments and studies of habitat features and prey abundance–and changes in key ecological interaction–will remain important components in assessing impacts. Promising future work lies in such areas as predictive modeling to assess the distributions of both whales and their prey, advancing noise-quieting and other technologies, quantifying substantial changes in prey distribution and other habitat features, studying individual whale health, and eDNA analyses.

Overall, it remains difficult to assess the relative importance of specific activities (e.g., OSW turbine construction and operation) and their overall contributions to impacts on NARW amid a suite of other possibly impinging variables, such as climate change and natural variation in environmental features. Care must be taken to develop this industry wisely, with proactive measures in place to minimize and mitigate the potential impacts (e.g., from noise, vessel strikes) identified for the vulnerable NARW. Studies capable of detecting and determining the extent of actual impacts from OSW activities are needed so that we can determine the extent to which protective measures have addressed concerns, whether potential threats are revealed to be minimal, and therefore to advise how precautionary the industry must be as it continues to grow. The results of these current and future studies will facilitate the implementation of more specific measures to reduce the impacts.

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Appendix A: Information Requested and Questions to be Addressed in an Online Survey Conducted by Blue World Research Institute

a. Email Address:

b. First and Last Name:

c. Organization:

d. Primary Investigator (PI) or Lead Researcher:

e. Other researchers involved?

f. Project Objective(s):

g. Geographic Location (e.g., coast-wide (or range-wide) or coastal area where work will take place):

h. Geographic Scope (e.g., species range-wide, broadscale, specific to a particular area or set of individuals):

i. Methods:

j. Dates and Timelines (e.g., initiation date (season or year is suitable), expected initiation date if not yet started, expected conclusion time. Also indicate also if the project is seasonal, multi-year, and/or expected to be ongoing):

k. Outcome(s), Products(s) or Expected Outcomes (what did the study yield or expect to yield?):

l. Contribution (or expected contribution) to NARW Conservation or Impact Reduction:

m. Expected Pitfalls or Challenges (e.g., insufficient sample sizes, funding, weather or logistical limitations):

n. We expect to bin studies by type. Please indicate which of the following best applies to your study:

    a. __ NARW population status and monitoring
    b. __ Assessing impacts to NARWs from wind energy development and/or detecting population
    c. effects from impacts
    d. __ New or emerging approaches for reducing impacts to NARW
    e. __ Assessing the relative effectiveness of impact-reduction measures
    f. __ Other. Explain: ____________________

b. If selected Other, please explain:

c. Future Work; Recommended Follow-on Studies or Next Logical Steps: (e.g.: 1) the work described may only be a piece of a larger puzzle, indicate what else might be needed to provide the missing pieces?; 2) What are the missing pieces, if any?; 3) What, in your view, are the highest priority areas for future work?; 4) In the suite of studies underway, where are the biggest gaps?; 5) Do you expect to receive funding for additional studies?

If so, what kind of studies and when would they take place?; 6) If you are engaged primarily in monitoring (e.g., population or impacts studies), do you expect it to be ongoing?; 7) Is funding assured, or perhaps uncertain?

d. Where, in your view, should BOEM and other possible funding sources focus future funding?
e. Would you like to provide any additional comments?
f. Do you have any conference or paper Abstracts, or published papers you would like to provide? If so, please upload them here (in order to do so, you must sign in with a Google account).
g. Would you like to be contacted for a follow-up discussion?
h. If yes, please provide preferred method of contact:

Appendix B: Summaries of the Objectives, Key Findings, and Conclusions of Several Workshops and Work Groups with Relevance to this Review

B.1 Best Management Practices Workshop for Atlantic Offshore Wind Facilities

A 2017 workshop on Best Management Practices [BMP] Workshop for Atlantic Offshore Wind Facilities and Marine Protected Species sought, among other things, to increase understanding of the science and regulations for protecting marine species from the effects of offshore wind development on the Atlantic OCS; and identify BMPs to avoid, minimize, and monitor the effects of offshore wind activities on marine protected species (BOEM 2018).

Among other things, the workshop recommended combining monitoring survey methods (e.g., visual and PAM data; incorporating both local scale PAM results with those on far greater scales); that relevant datasets be aggregated and synthesized to enhance the rigor and utility of existing data; but also at the same time recommended that datasets be segregated to facilitate studies in finite, rather than broad, geographic areas (presumably, to capture unique ecologic features in those areas or to accommodate specific WEAs). The workshop identified the need to standardize methods for recording and reporting monitoring data.

The workshop also noted that cumulative impact analyses are generally lacking, but that these assessments should be conducted on species-level, rather than individual level scales when conducted. The need for assessments of effects on behavior, particularly in real time, was identified. The workshop noted the uncertainties associated with such analyses. The need to conduct prey-based studies to help identify potential effects was also noted. In addition, a need was identified for further studies of sound propagation (especially for piling driving), best methods for mitigating the sound emitted, and determining the best technology for reducing the impact of sound; as was additional study of habitat use and seasonal timing, especially for determining annual variability and seasonal timing restrictions.

B.2 Workshop on a Framework for Studying the Effects of Offshore Wind Development on Marine Mammals and Turtles

A May 2018 workshop aimed to develop a framework to guide studies of potential impacts to endangered whales and sea turtles from offshore windfarm construction and operation in waters off the U.S. northeast (Kraus et al. 2019).

The workshop focused on Massachusetts and Rhode Island- Massachusetts Wind Energy Areas and developed a list of hypotheses for testing (e.g., “wind turbine presence affects long-term feeding opportunities for whales and sea turtles”) potential impacts from OSW development and operation and the types of data sources and collection approaches needed to address them.

The workshop identified possible biological consequences from OSW energy development most in need of addressing. Among these were construction activities or wind turbine presence resulting in whale or turtle displacement from the area(s) and/or changes in distribution, disruption of critical behavior, such as feeding, socializing, or nursing, and elevated stress hormone levels in these taxa. For additional detail on hypotheses developed, studies needed, and workshop conclusions see Kraus et al. (2019).

It also identified options to assess potential population-level impacts, including the immediate effects (e.g., disturbance or habitat displacement) of short-term construction activities at the project-specific scale, and potential long term and population-level impacts of windfarm operations on distribution, abundance, behavior, or demography of endangered marine mammals and sea turtles.

Displacement, disturbance, and physiological stressors were among the biological responses considered most important. Workshop participants cautioned that limited information on prey species abundance in WEAs will limit the ability to separate displacements effects from the possibility that animals may have sought better foraging circumstances in other locations. For example, plankton and prey fish studies may be important in determining the cause and effect of any construction or post-construction activities on marine mammal and sea turtle distributions.

Emphasis was placed on the use of PCoD modeling to test hypotheses about the effects on a given population.

The workshop noted that existing population consequences modeling efforts are currently mostly hypothetical, behavioral and physiological responses to impulsive sounds would help validate the models, and studies of sound impacts from wind energy installations should be designed to contribute to PCoD or PCoMS models. The workshop also concluded that impact studies (including sound) should be designed to contribute to PCoD or PCoMS models and specific parameters for these models should be considered with each investigation.

The workshop recommended updating spatial density models for various WEA and that survey (both aircraft and PAM) data from specific WEA data be incorporated into revised models. Tagging studies can were acknowledged to be able to help detect behavioral changes in response to construction activities, and a review of existing tagging study data would help determine the feasibility and efficacy of additional tagging studies, both approaches were recommended. Also recommended was a review of passive acoustic studies to determine the most appropriate design for acoustic studies (involving multiple species) including power analyses to detect changes in call rates over time. Last, biological oceanography (i.e., zooplankton) modeling studies were recommended for a better understanding of the processes that affect prey patches.

B.3 State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts

In November 2020, the New York State Energy Research and Development Authority (NYSERDA) convened a State of the Science (SOTS) Workshop ‘to assess the state of the knowledge regarding offshore wind development’s potential cumulative impacts on wildlife populations and ecosystems.’ Following this, NYSERDA established separate workgroups for various marine taxa, including marine mammals, to identify research and coordination needs to address cumulative impacts from OSW energy development. The geographic scope for the deliberations about impacts was primarily from southern New England to North Carolina. In 2021 the marine mammal workgroup issued a report of its findings which included lists of prioritized research topics (Southall et al. 2021).

The workgroup concluded that baleen whales were the highest priority for research relative to OSW energy development and operations due to the conservation status of many species in this group, as well as the relative lack of information on their potential interactions with OSW development. Studies identified as being among the highest-ranking, short-term priorities included: a) estimating habitat use, distribution, and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns; b) establishing individual baseline movements and behavioral patterns (foraging, diving, reproduction, etc.) in OSW development areas; and c) identifying acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment.

However, other than identifying studies with various levels of priority (determined through workgroup member polling), the workgroup did not identify how the intended studies listed were to be used to assess cumulative impacts from OSW energy activities. Instead, it indicated that data obtained from the various studies identified could be used in consequence models (such as PCoD) (Booth et al. 2020). SOTS meetings occur on an annual basis.

B.4 Atlantic Scientific Review Group (ASRG)

Regional Scientific Review Groups were established under Section 117 of the MMPA to advise the NMFS and the U.S. Fish and Wildlife Service to provide advice on a range of marine mammal science and management issues including, for example, marine mammal stock abundance estimates and trends; impacts of habitat destruction and appropriate conservation or management measures to minimize any such impacts; and research needed to identify modifications in fishing gear and practices likely to reduce the incidental mortality and serious injury of marine mammals in commercial fishing operations.

The ASRG meets periodically and provides advice on the status of marine mammal stocks off the Atlantic and Gulf Coasts. Some recent ASRG recommendations are relevant to this review.

In its 16 March 2021 letter to NMFS,[3] the ASRG noted the increased number of NARWs with evidence of sub-lethal trauma, the link between variability in nutrition and variability in NARW calving rates, and possible increased energy expenditures as related to non-lethal entanglements (e.g., Pettis et al. 2017). Therefore, the Group noted the importance of understanding the relationship between nutrition and entanglement and other stressors such as sub-lethal vessel strikes and noise in the NARW energetic budgets. As a result, the Group urged the development and use of the health assessment tools and approaches identified in the 2019 workshop on the subject (Fauquier et al. 2020, Moore et al. 2021; summaries of these projects are provided in Appendix C).

Related to this, the ASRG noted the importance of the Strategic Environmental Research and Development Program's (SERDP) project (Tyack 2020, University of St. Andrews; a summary of this project is provided in Appendix C) on modeling PCoMS on marine mammals and highlighted the need for additional data to parameterize these models in understanding the demographic effects of sub-lethal trauma.

In addition, the ASRG also commended NMFS for the development, updating, and refining of the NARW Decision Support Tool (DST) which is designed to assess risk-reduction benefits of different management strategies. While the tool is, at present, primarily geared to entanglement and NARW interactions, the ASRG pointed to the need to couple the DST with other population evaluation tool models under development, to design a tool for a broader management strategy evaluation.

B.5 Workshop on New York Bight Passive Acoustic Monitoring

Held on 19–22 October 2020, a workshop on PAM networks and data standards, focused on: 1) identifying commonalities in current New York Bight (NYB) PAM data resources and opportunities for collaboration and data synthesis; 2) the importance of data collection and analysis standardization across projects; and 3) identifying PAM research priorities and opportunities for collaboration, both within the NYB and across the mid-Atlantic region (WCS 2021).

[3] https://media.fisheries.noaa.gov/2021-08/ASRG%20letter%20to%20NMFS%20March%202021.pdf

The workshop concluded that developing reporting standards and a shared data repository (ideally on a regional level) was key for maximizing data resources and facilitating data sharing across projects and would essentially provide the framework for coordinated PAM projects. It also noted the importance of synthesizing all available PAM data and integrating other data sources (visual surveys and environmental data) to establish a baseline understanding of cetacean distribution and interaction with environmental variables in the NYB. All participants supported the need for a project focused on investigating vessel collision risk and shipping noise-related impacts on cetaceans. Although a project on vessel collision risk and noise impacts may require substantial resources, it is vital information for mitigation and management decisions for the heavily trafficked NYB and particularly as OSW development expands in the region in coming years.

Workshop recommendations included developing an informal working group the goal of refining project ideas for current and forthcoming data, discussing regional efforts, and identifying potential funding sources for synthesis efforts; establishing local and/or regional PAM data standards and a shared data repository that would provide a foundation for collaboration across both local and regional projects; the development of a NYB (and ultimately regional) PAM network with standardized data collection and reporting standards and with the potential for real-time sensors to inform best-practices and mitigation, so that long-term, broad-scale questions could be answered and provide information necessary for species protection in the region.

B.6 Wildlife and Offshore Wind

In 2021, the U.S. Department of Energy and BOEM funded a multi-year project entitled Wildlife and Offshore Wind (Wildlife and Offshore Wind 2023), involving multiple research organizations, to evaluate the potential effects of OSW energy development on marine wildlife. The group intends to analyze data gaps, develop risk assessment and research frameworks, conduct technology validation, and provide a long-term, adaptive roadmap to assess potential effects.

Appendix C: Summary of Relevant Studies Related to BOEM, NARW, and OSW

Table C-1. Passive acoustic monitoring studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Addressing Key Information Gaps in Acoustic Ecology of North Atlantic Right Whales (NT-23-01)	Gather biologging data on the acoustic behavior of the NARW in the Mid-Atlantic to to 1) improve abundance estimates; 2) increase the value of existing PAM data; 3) inform the assessment of the effectiveness of PAM as a mitigation strategy for these priority ESA-listed species; and 4) provide, short term habitat usage and movements of these species to assist in identifying currently unknown potentially important biological areas.	BOEM	J. Levenson	Ongoing. Levenson, J. 2022. Addressing key information gaps in acoustic ecology of North Atlantic right whales (NT-23-01). Sterling (VA): Department of the Interior, Bureau of Ocean Energy Management. https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/NT-23-01.pdf
Coastal Acoustic Buoy for Offshore Wind (CABOW)	Develop cost-effective and robust exclusion zone PAM mitigation approach.	Sea Mammal Research Unit	J. Wood	Wood, J (SMRU Consulting, St Andrews, UK). 2021. Coastal acoustic buoy for offshore wind. Washington (DC): US Department of Energy, Office of Energy Efficiency and Renewable Energy. 9 p. https://www.energy.gov/sites/default/files/2021-09/fy21peerreview-environmentalresearch-smru-wood.pdf
Determining habitat use by marine mammals and ambient noise levels using passive acoustic monitoring offshore of Maryland. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-018	Conduct passive acoustic monitoring for three years to characterize underwater ambient sound levels and identify vocalizing marine mammal species within and around the Maryland Wind Energy Area (WEA)	University of Maryland, Center for Environmental Science	H. Bailey	Bailey H, Rice A, Wingfield JE, Hodge KB, Estabrook BJ, et al. (University of Maryland Center for Environmental Science, Cambridge, MD) 2018. Determining habitat use by marine mammals and ambient noise levels using passive acoustic monitoring offshore of Maryland. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 229 p. Obligation No.: M14AC00018. Report No.: OCS Study BOEM 2019-018.

Project Title	Project Objective	Organization	PI or Lead	Reference
Evaluating the Accuracy and Detection Range of a Moored Whale Detection Buoy near the Massachusetts Wind Energy Area	(1) evaluate the accuracy of a large whale species detection and species identification buoy using near real-time detections of right, humpback, sei, and fin whales through simultaneous acoustic recordings and visual sightings, and (2) characterize the detection range of the system for right whales using collocated hydrophone arrays capable of localizing calling whales.	Woods Hole Oceanographic Institute	M. Baumgartner	Baumgartner MF, Lin Y-T. 2019. Evaluating the accuracy and detection range of a moored whale detection buoy near the Massachusetts Wind Energy Area. Sterling (VA); Boston (MA): U.S. Department of the Interior, Bureau of Ocean Energy Management; Massachusetts Clean Energy Center. 72 p. Obligation No.: M17AC00012. Report No.: OCS Study BOEM 2019-061.
Evaluation of the Coastal Acoustic Buoy for offshore wind for real time mitigation of North Atlantic right whales	Design/build/test hardware and software of the PAM mitigation system in the field	Sea Mammal Research Unit	K. Palmer	Palmer K, Turner J, Tabbutt J, Gillespie D, Thompson J, King P, Wood J. 2021. Evaluation of the Coastal Acoustic Buoy for offshore wind for real time mitigation of North Atlantic right whales. J Acoust Soc Am. 150(4):A48-A49. DOI: 10.1121/10.0007588
Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales	Determine right whale distributions and changes in distribution using passive acoustics	NOAA Fisheries; University of Massachusetts Boston	G. Davis	Davis GE, Baumgartner MF, Bonnell JM, Bell J, Berchok C, et al. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (Eubalaena glacialis) from 2004 to 2014. Sci Rep. 7(13460). doi 10.1038/s41598-017-13359-
Management of acoustic metadata for bioacoustics	Organize and store acoustic metadata in Tethys, a passive acoustic monitoring database co-funded by BOEM and the National Oceanographic Partnership Program (http://tethys.sdsu.edu/)	San Diego State University	M. Roch	Roch MA, Batchelor H, Baumann-Pickering S, Berchock CL, Cholewiak D, et al. 2016. Management of acoustic metadata for bioacoustics. Ecol Inform. 31:122-136.

Project Title	Project Objective	Organization	PI or Lead	Reference
Near real-time detection of low-frequency baleen whale calls from an autonomous surface vehicle	Monitor low-frequency baleen whale calls	Woods Hole Oceanographic Institute `	M. Baumgartner	Baumgartner M, Ball K, Partan J, Pelletier L-P, Bonnell J, et al. 2021. Near real-time detection of low-frequency baleen whale calls from an autonomous surface vehicle: implementation, evaluation, and remaining challenges. J Acoust Soc Am. 149:2950-2962.
North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: implications for management.	Develop a better understanding of right whale occurrence the mid-Atlantic US coast is relative to offshore wind energy development activities.	Bioacoustics Research Program, Cornell University	K.B. Hodge	Hodge KB, Muirhead CA, Morano JL, Clark CW, Rice AN. 2015. North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: implications for management. Endang Species Res. 28:225-234. https://doi.org/10.3354/esr00683
Project WOW IRES - passive acoustic monitoring	Acoustically detect the presence of North Atlantic right whales (NARW), fin whales, sei whales, minke whales, and humpback whales within the New York Bight, Massachusetts, and Rhode Island winder energy areas using archival acoustic recording units.	Wildlife and Offshore Wind	D. Nowacek	Ongoing. https://database.rwsc.org/details?recordId=recUumQ6ig3wafJqj https://offshorewind.env.duke.edu/
Tethys: A workbench and database for passive acoustic metadata	Organize and store acoustic metadata in Tethys, a passive acoustic monitoring database co-funded by BOEM and the National Oceanographic Partnership Program (http://tethys.sdsu.edu/)	San Diego State University	M. Roch	Roch MA, Baumann-Pickering S, Batchelor H, Hwang D, Širović A, et al. 2013. Tethys: a workbench and database for passive acoustic metadata. In: Proceedings: 2013 Oceans; September 23–27, 2013; San Diego, CA. Piscataway (NJ): IEEE. [accessed 25 May 2023]; https://ieeexplore.ieee.org/abstract/document/6741361

Project Title	Project Objective	Organization	PI or Lead	Reference
Whales of New York	Investigate the temporal (2016 – 2022) and spatial (SE vs. NW buoys in 2020 – 2022) presence of whales in the Empire Wind Lease Area in the New York Bight and to provide near-real time acoustic detections of whales for educational and potential mitigation purposes. Analyze archived acoustic recordings to investigate the species' vocal behavior and ambient ocean noise conditions.	WCS, WHOI, Equinor	Murray, A.	Ongoing. Murray A, Rekdahl ML, Baumgartner MF, Rosenbaum HC. 2022. Acoustic presence and vocal activity of North Atlantic right whales in the New York Bight: Implications for protecting a critically endangered species in a human-dominated environment. Conservat Sci and Prac. 4(11). doi:10.1111/csp2.12798. [accessed 2023 May 22]. https://onlinelibrary.wiley.com/doi/10.1111/csp2.12798.

Table C-2. Vision-enhanced observations studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Comparing methods suitable for monitoring marine mammals in low visibility conditions during seismic surveys	Review and evaluate active acoustic monitoring, PAM, RADAR, and thermal IR monitoring methods when applied to marine mammal monitoring for mitigation purposes on a seismic survey vessel	Sea Mammal Research Unit	U.K. Verfuss	Verfuss UK, Gillespie D, Gordon J, Marques TA, Miller B, et al. 2018. Comparing methods suitable for monitoring marine mammals in low visibility conditions during seismic surveys. Mar Pollut Bull. 126(1):1-18
Review of Night Vision Technologies for Detecting Cetaceans from a Vessel at Sea	Review literature, plus some preliminary field data, on night vision devices to detect marine mammals in low-light conditions	Smultea Environmental Sciences	M. Smultea	Smultea M, Silber GK, Donlan P, Fertl D, Steckler D (Smultea Environmental Sciences, Issaquaah, WA). 2021. Review of night vision technologies for detecting cetaceans from a vessel at sea. Report prepared for South Fork Wind. Boston (MA): Ørstead North America. 79 p. https://www.smulteasciences.com/publications-subjectmatterexpertise

Table C-3. Tagging and telemetry studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Developing the Next Generation of Animal Telemetry: A Partnership to Develop Cost Effective, Open-Source, Marine Megafaunal Tracking (NSL #NT-17-x20)	Develop an alternative method of OCS marine animal tracking by leveraging NASA's CubeSat partnerships with STEM universities and the Automatic Packet Reporting System (APRS) which is an amateur radio-based system for real time digital communications with transceivers located on land and low-earth orbit using NASA's CubeSat program.	NASA	A. Martinez	NASA. 2018. Developing the Next Generation of Animal Telemetry: A Partnership to Develop Cost Effective, Open-Source, Marine Megafaunal Tracking. NASA Summary Chart. Report T0199. 1p. https://flightopportunities.ndc.nasa.gov//media/technology/202/199-summary-chart.pdf

Table C-4. Regional or site-specific survey studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US waters of the Western North Atlantic Ocean	Assess the abundance, distribution, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic state and outer continental shelf waters, and evaluate them in an ecosystem context	NOAA's Northeast Fisheries Science Center, NEFSC, SEFSC	NEFC and SEFSC	[NEFSC and SEFSC] National Marine Fisheries Service, Northeast Fisheries Science Center (Woods Hole, MA) and Southeast Fisheries Science Center (Miami, FL). 2021. 2020 Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the Western North Atlantic Ocean–AMAPPS III. Woods Hole (MA): NOAA Fisheries. 41 p. https://repository.library.noaa.gov/view/noaa/29491
Atlantic Marine Assessment Program for Protected Species: 2010-2014	Assess the abundance, distribution, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic state and outer continental shelf waters, and evaluate them in an ecosystem context	NOAA's Northeast Fisheries Science Center, NEFSC, SEFSC	D. Palka	Palka DL, Chavez-Rosales S, Josephson E, Cholewiak D, Haas HL, et al. (National Marine Fisheries Science Center, Woods Hole, MA and Key Biscayne, FL; US Fish and Wildlife Service, Laurel, MD). 2017. Atlantic Marine Assessment Program for Protected Species [AMAPPS]: 2010–2014. Washington (DC): US Department of the Interior, Bureau of Ocean Energy Management. Obligation No.: M10PG00075. Report No.: OCS Study BOEM 2017-071.
Atlantic Marine Assessment Program for Protected Species: FY15 – FY19	Assess the abundance, distribution, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic state and outer continental shelf waters, and evaluate them in an ecosystem context	NOAA's Northeast Fisheries Science Center	D. Palka	Palka D, Aichinger DL, Broughton E, Chavez-Rosales S, Cholewiak D, et al. (National Marine Fisheries Science Center, Woods Hole, MA and Key Biscayne, FL) 2021. Atlantic Marine Assessment Program for Protected Species [AMAPPS]: FY15–FY19. Washington (DC): US Department of the Interior, Bureau of Ocean Energy Management. 330 p. Obligation No.: M14PG00005. Report No.: OCS Study BOEM 2021-051.

Project Title	Project Objective	Organization	PI or Lead	Reference
Baseline Bioacoustic Characterization for Offshore Renewable Energy Development in the North Carolina and Georgia Wind Planning Areas	Establish a baseline of seasonal activity for three baleen whale species along the U.S. Atlantic coast to identify the potential environmental impact of offshore wind energy construction.	The Bioacoustics Research Program, Cornell University's Laboratory of Ornithology, in collaboration with ESS Group, Inc. and Marine Acoustics, Inc.	A. Rice	Rice AN, Morano JL, Hodge KB, Salisbury DP, Muirhead CA, et al. (Cornell Laboratory of Ornithology, Cornell University, Ithaca, NY). 2014. Baseline bioacoustic characterization for offshore alternative energy development in North Carolina and Georgia Wind Planning Areas. New Orleans (LA): US Dept. of the Interior, Bureau of Ocean Energy Management. 190 p. Obligation No.: M10PC00087. Report No.: OCS Study BOEM 2015-026.
Ecological Baseline Study of the U.S. Outer Continental Shelf Off Maine (AT 22-12)	Gather information on the distribution and abundance of marine mammal, bird, and sea turtle species in the Gulf of Maine to assist in the environmental review of impacts from floating offshore wind energy development using seasonal High-Resolution Aerial and/or Boat-based Wildlife Surveys.	BOEM, Biodiversity Research Institute, HiDef Aerial Surveying Ltd	D. Bigger	Ongoing. Bigger, D. 2022. Ecological Baseline Study of the U.S. Outer Continental Shelf Off Maine (AT 22-12). Bureau of Ocean Energy Management. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Ecological-Baseline-Study-of-the-US-Outer-Continental-Shelf-Off-Maine.pdf
Maine aerial surveys	Conduct systematic aerial surveys of waters off Maine from September 2023 – January 2025 to build a data set to estimate abundance for species with an adequate number of sightings.	New England Aquarium	New England Aquarium	Ongoing. https://database.rwsc.org/details?recordId=recGfijPbg4Y8zIV7
Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales	Estimate distribution and relative abundance of large whales and turtles MA and the Rhode Island/Massachusetts WEA; and to assess prey species and oceanographic conditions near right whale aggregations in the WEA	New England Aquarium, Woods Hole Oceanographic Institution	O. O'Brien	O'Brien O, McKenna K, Hodge B, Pendleton D, Baumgartner M, Redfern J (New England Aquarium, Boston, MA; Woods Hole Oceanographic Institution, Woods Hole, MA). 2021. Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Summary Report Campaign 5, 2018–2019. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 83 p. Obligation No.: M17AC00002. Report No.: OCS Study BOEM 2021-033.

Project Title	Project Objective	Organization	PI or Lead	Reference
New York Bight Whale Monitoring Aerial Surveys	Determine the distribution, density, and abundance of blue, fin, humpback, North Atlantic right whale, sei, and sperm whales.	New York State Department of Environmental Conservation; Tetra Tech and LGL	Tetra Tech and LGL	Tetra Tech (Oakland, CA) and LGL Ecological Research Associates, Inc. (Bryan, TX). 2020. Final comprehensive report for New York Bight Whale Monitoring Aerial Surveys, March 2017–February 2020. East Setauket (NY): New York State Department of Environmental Conservation, Division of Marine Resources. 136 p. https://www.dec.ny.gov/docs/fish_marine_pdf/mmaeran3.pdf
North Atlantic Right Whale Calving/Nursery Area Surveys: 2015/2016	Contribute to NARW population monitoring especially cow/calf pairs; and monitoring trends in human-related serious injuries and mortality.	NOAA Fisheries, SERO; Florida Fish and Wildlife Conservation Commission and collaborators	C. Surrey-Marsden	Surrey-Marsden C, Howe K, White M, George C, Gowan T, et al. 2018. North Atlantic right whale calving area surveys: 2015/2016 results. St. Petersburg (FL): National Oceanic and Atmospheric Administration, National Marine Fisheries Service. NOAA Tech Memo NMFS-SER-6. [accessed 24 May 2023]; https://repository.library.noaa.gov/view/noaa/17112
North Atlantic Right Whale Monitoring and Surveillance	Improve understanding of population status by identifying and tracking essential population metrics, and improve understanding of distribution and habitat use.	NOAA Fisheries	E.M. Oleson	Oleson EM, Baker J, Barlow J, Moore J, Wade P. 2020. North Atlantic right whale monitoring and surveillance: report and recommendations of the National Marine Fisheries Service's Expert Working Group. Silver Spring (MD): National Marine Fisheries Service. Report No.: NOAA Tech. Memo. NMFS-F/OPR-64.
Northeast large pelagic survey collaborative aerial and acoustic surveys for large whales and sea turtles.	Collect visual and acoustic baseline data on distribution, abundance, and temporal occurrence patterns of marine mammals, in particular endangered whales and sea turtles, in the MA WEA and RIMA WEA; assess the degree of inter-annual variability in animal distributions;, and to integrate aerial survey, acoustic, and photographic survey data on endangered large whales and sea turtles to provide an overview of habitat-use patterns.	BOEM	S.D. Kraus	Kraus SD, Leiter S, Stone K, Wikgren B, Mayo C, et al. (New England Aquarium, Boston, MA; Provincetown Center for Coastal Studies, Provincetown, MA; University of Rhode Island, Narragansett, RI; Cornell University, Ithaca, NY). 2016. Northeast large pelagic survey collaborative aerial and acoustic surveys for large whales and sea turtles: final report. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. Obligation No.: M12AC00024. Report No.: OCS Study BOEM 2016-054.

Project Title	Project Objective	Organization	PI or Lead	Reference
Project WOW IRES - aerial surveys	Small-scale, aerial surveys over wind energy areas in southern New England, NY Bight that record marine fauna with a high-performance digital camera.	Wildlife and Offshore Wind	D. Nowacek	Ongoing. https://database.rwsc.org/details?recordId=recN2rN20QHyyIPQx https://offshorewind.env.duke.edu/
Southern New England marine mammal and sea turtle aerial surveys: Campaign 1-3	Conduct aerial and acoustic surveys in the Massachusetts wind energy area to estimate abundance of large whales (right, minke, fin) and sea turtles. Seven campaigns were finished between 2011- 2022.	New England Aquarium, Massachusetts Clean Energy Center, BOEM	New England Aquarium, Massachusetts Clean Energy Center, BOEM	Kraus SD, Leiter S, Stone K, Wikgren B, Mayo C, et al. (New England Aquarium, Boston, MA; Provincetown Center for Coastal Studies, Provincetown, MA; University of Rhode Island, Narragansett, RI; Cornell University, Ithaca, NY). 2016. Northeast large pelagic survey collaborative aerial and acoustic surveys for large whales and sea turtles: final report. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. Obligation No.: M12AC00024. Report No.: OCS Study BOEM 2016-054.
Southern New England marine mammal and sea turtle aerial surveys: Campaign 4	Conduct aerial and acoustic surveys in the Massachusetts wind energy area to estimate abundance of large whales (right, minke, fin) and sea turtles. Seven campaigns were finished between 2011- 2022.	New England Aquarium, Massachusetts Clean Energy Center, BOEM	New England Aquarium, Massachusetts Clean Energy Center, BOEM	Quintana, E., Kraus, S., Baumgartner, M (New England Aquarium, Boston, MA). 2018. Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales Summary Report – Campaign 4, 2017-2018. New England Aquarium Report.
Southern New England marine mammal and sea turtle aerial surveys: Campaign 5	Conduct aerial and acoustic surveys in the Massachusetts wind energy area to estimate abundance of large whales (right, minke, fin) and sea turtles. Seven campaigns were finished between 2011- 2022.	New England Aquarium, Massachusetts Clean Energy Center, BOEM	New England Aquarium, Massachusetts Clean Energy Center, BOEM	O'Brien O, McKenna K, Hodge B, Pendleton D, Baumgartner M, Redfern J (New England Aquarium, Boston, MA; Woods Hole Oceanographic Institution, Woods Hole, MA). 2021. Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Summary Report Campaign 5, 2018–2019. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 83 p. Obligation No.: M17AC00002. Report No.: OCS Study BOEM 2021-033.

Project Title	Project Objective	Organization	PI or Lead	Reference
Southern New England marine mammal and sea turtle aerial surveys: Campaign 6a	Conduct aerial and acoustic surveys in the Massachusetts wind energy area to estimate abundance of large whales (right, minke, fin) and sea turtles. Seven campaigns were finished between 2011- 2022.	New England Aquarium, Massachusetts Clean Energy Center, BOEM	New England Aquarium, Massachusetts Clean Energy Center, BOEM	O'Brien O, McKenna K, Pendleton D, Redfern J (New England Aquarium, Boston, MA). 2021. Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Interim Report Campaign 6A, 2020. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 41 p. Obligation No.: M17AC00002. Report No.: OCS Study BOEM 2021-054.
Southern New England marine mammal and sea turtle aerial surveys: Campaign 6b	Conduct aerial and acoustic surveys in the Massachusetts wind energy area to estimate abundance of large whales (right, minke, fin) and sea turtles. Seven campaigns were finished between 2011- 2022.	New England Aquarium, Massachusetts Clean Energy Center, BOEM	New England Aquarium, Massachusetts Clean Energy Center, BOEM	O'Brien O, McKenna K, Pendleton D, Redfern J (New England Aquarium, Boston, MA). 2022. Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Final Report Campaign 6B, 2020-2021. Boston (MA): Massachusetts Clean Energy Center.51 p. https://www.masscec.com/sites/default/files/documents/Campaign_6B_Final_Report.pdf
Understanding Marine Mammal Presence in the Virginia Offshore Wind Energy Area. BOEM 2019-007	Determine current, pre-construction conditions and behavior of protected cetacean species within the Virginia WEA and along the continental shelf, and to identify risks and potential human impacts of wind energy development.	Cornell University	D.P. Salisbury	Salisbury DP, Estabrook BJ, Klinck H, Rice AN. (Cornell University, Ithaca, NY). 2018. Understanding marine mammal presence in the Virginia Offshore Wind Energy Area. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 116 p. Obligation No.: M15AC00010. Report No.: OCS Study BOEM 2019-007.

Table C-5. Prey studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Biodiversity and Ecosystem Function in the Gulf of Maine: Pattern and Role of Zooplankton and Pelagic Nekton	Synthesize current data on species diversity of zooplankton and pelagic nekton, including compilation of observed species and descriptions of seasonal, regional and cross-shelf diversity patterns	Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, Nova Scotia, Canada	C. Johnson	Johnson CL, Runge JA, Curtis KA, Durbin EG, Hare JA, et al. 2011. Biodiversity and ecosystem function in the Gulf of Maine: Pattern and role of zooplankton and pelagic nekton. PLoS ONE. 6(1): e16491. https://doi.org/10.1371/journal.pone.0016491
Coastal amplification of supply and transport (CAST): a new hypothesis about the persistence of Calanus finmarchicus in the Gulf of Maine	Understand the long-term variability of C. finmarchicus in the Gulf of Maine and how that influences the NARW feeding grounds in the NE Atlantic	Woods Hole Oceanographic Institution	R. Ji	Ji R, Feng Z, Jones BT, Thompson C, Chen C, et al. 2017. Coastal amplification of supply and transport (CAST): a new hypothesis about the persistence of Calanus finmarchicus in the Gulf of Maine. ICES J Mar Sci. 74(7)1865–1874. doi:10.1093/icesjms/fsw253
Investigating Persistent Super Aggregations of Right Whales and Their Prey in Lease Areas OCS-A 0521 and OCS-A 0522 in the North Atlantic (AT-22-13)	Conduct multidisciplinary research to gain insight into the prey resources that compress right whales into super aggregations in wind energy lease areas OCS-A 0521 and OCS-A 0522.	NMFS Office of Renewable Energy Programs	H. Walsh	Ongoing. Investigating persistent super aggregations of right whales and their prey in lease areas OCS-A 0521 and OCS-A 0522 in the North Atlantic. National Marine Fisheries Service, Office of Renewable Energy Programs Report No.: Environmental Studies Program: Studies Development Plan | FY 2022–2023, AT-22-13. https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/AT-22-13.pdf
Zooplankton Ecology of the Gulf of Maine	Understand the long-term variability of C. finmarchicus in the Gulf of Maine and how that influences the NARW feeding grounds in the NE Atlantic	University of Maine	J. Runge	Report under review. Zooplankton ecology of the Gulf of Maine (AT 18-x01). Program document of BOEM and the University of Maine. 1p. https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/AT-18-x01.pdf

Table C-6. Stress and health studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Assessing North Atlantic right whale health: threats, and development of tools critical for conservation of the species	Review the NARW health assessment literature, NARW Consortium databases, and efforts and limitations to monitor individual and species health, survival, and fecundity	Woods Hole Oceanographic Institute	M. Moore	Moore MJ, Rowles TK, Fauquier DA, Baker JD, Biedron I, et al. 2021. Review: Assessing North Atlantic right whale health: threats, and development of tools critical for conservation of the species. Dis Aquat Organ. 2021 Feb 25 (143):205-226. [accessed 31 May 2023]; doi: 10.3354/dao03578. PMID: 33629663
Report of the Health Assessment Workshop for North Atlantic Right Whales (Eubalaena glacialis), June 24-26, 2019	(1) assess current health information data, including associated data gaps, and (2) identify appropriate available and needed tools and techniques for collecting standardized health data that can be used to understand health effects of environmental and human impacts (e.g., entanglement), and inform fecundity and survivorship models to ultimately guide population recovery of North Atlantic right whales	NOAA NMFS	D. Fauquier	Fauquier D, Long K, Biedron I, Wilkin S, Rowles T, et al. 2020. Report of the health assessment workshop for North Atlantic right whales *Eubalaena glacialis*, June 24–26, 2019. Silver Spring (MD): National Oceanic and Atmospheric Administration Office of Protected Resources. Report No.: NOAA Tech. Memo. NMFS-OPR-65. https://www.fisheries.noaa.gov/resource/document/report-health-assessment-workshop-north-atlantic-right-whales-eubalaena-glacialis

Table C-7. Distribution and/or spatial density modeling studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Final Project Report: Marine Species Density Data Gap Assessments and Update for the AFTT Study Area, 2016-2017.	Develop comprehensive and detailed models of cetacean density in the U.S. east coast and Gulf of Mexico	Marine Geospatial Ecology Lab, Duke University	J. Roberts	Roberts JJ, Mannocci L, Halpin PN (Marine Geospatial Ecology Lab, Duke University, Durham, NC). 2017. Final project report: marine species density data gap assessments and update for the AFTT Study Area, 2016-2017 (Opt. Year 1). 76 p. Norfolk (VA): Naval Facilities Engineering Command, Atlantic. Cooperative Agreement No.: N62470-15-2-8003.
Habitat-based cetacean density models	Develop comprehensive and detailed models of cetacean density in the U.S. east coast and Gulf of Mexico	Marine Geospatial Ecology Lab, Duke University	J. Roberts	Roberts JJ, Best BD, Mannocci L, Fujioka E, Halpin PN, et al. 2016. Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico. Sci Rep. 6(1): 22615. doi: 10.1038/srep22615.

Table C-8. Predictive modeling studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Assessing Population Effects of Offshore Wind Development on North Atlantic Right Whales (AT-21-01)	Convening workshops and meetings to review of existing information, develop a report and predictive model for the bioenergetic consequences of behavioral disturbance, and identify future research and monitoring needs would address the lack of information regarding the bioenergetics of North Atlantic right whales due to the construction and operation of wind farms.	BOEM, University of St. Andrews	K. Baker.	Ongoing. Baker, K. 2022. Assessing population effects of offshore wind development on North Atlantic right whales (AT-21-01). BOEM. https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/Assessing%20Population%20Effects%20of%20Offshore%20Wind%20Development%20on%20North%20Atlantic%20Right%20Whales.pdf
Predicting occurrence and habitat occupancy of NARWs	Determine water-borne Dimethyl sulfide (DMS) concentrations to predict occurrence and site occupancy of NARWs	NOAA/Stellwagen Bank National Marine Sanctuary	K. Owen	Owen K, Saeki K, Warren JD, Bocconcelli A, Wiley DN, et al. 2021. Natural dimethyl sulfide gradients would lead marine predators to higher prey biomass. Commun Biol. 4:149. https://doi.org/10.1038/s42003-021-01668-3

Table C-9. Impact modeling studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Cumulative Stresses Affecting Endangered North Atlantic Right Whales	Determine if and how one or more human and natural stressors may compound the effects of the others.	Duke University	D. Nowacek and R. Schick	Duke University Nicholas School of the Environment. 26 March 2021. New grant funds study on cumulative stresses affecting endangered North Atlantic right whales. Durham (NC): Duke University. [accessed 26 May 2023] https://nicholas.duke.edu/news/new-grant-funds-study-cumulative-stresses-affecting-endangered-north-atlantic-right-whales
Marine Mammals Workgroup Report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts	Summarize the results of the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts	New York State Environmental Technical Working Group	B. Southall	Southall B, Morse L, Williams KA, Jenkins E. 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 p. Available at https://www.nyetwg.com/2020-workgroups .
Towards an Understanding of the Cumulative Effects of Multiple Stressors on Marine Mammals – an Interdisciplinary Working Group with Case Studies	(1) develop quantitative methods to predict behavioral or physiological responses to two or more stressors and apply these approaches in case studies, (2) use the results to help construct a Population Consequences of Multiple Stressors (PCoMS) model for each case study, (3) develop and/or evaluate new technologies to assess adverse health and ecosystem-level effects, (4) and promote information exchange by interacting with researchers and managers working on cumulative effects.	University of St Andrews	P. Tyack	Tyack, P. 2020. Towards an understanding of the cumulative effects of multiple stressors on marine mammals–an interdisciplinary working group with case studies. Ongoing study for Strategic Environmental Research and Development Program (SERDP) RC20-1097. https://serdp-estcp.org/projects/details/5242e16d-3972-45cb-a83a-51b43bd877fb.

Table C-10. Risk assessment studies

Project Title	Project Objective	Organization	PI or Lead	Reference
Risk Assessment to Model Encounter Rates Between Large Whales and Vessel Traffic from Offshore Wind Energy on the Atlantic OCS	(1) characterize the risk of vessel strikes on large whales and sea turtles from different vessel types that operate in support of Atlantic OCS wind energy areas, (2) to develop a model that accounts for geospatial, temporal, and species-specific parameters in the vessel operations area for these wind energy areas, (3) identify the most sensitive parameters for vessel type, operation, and species conditions that contribute to the potential for vessel strikes in order to produce an analytical framework for assessing strike risk associated with offshore wind development.	CSA Ocean Sciences Inc.	M.J. Barkaszi	Barkaszi MJ, Fonesca M, Foster T, Malhotra A, Olsen K (CSA Ocean Sciences Inc., Stuart, FL). 2021. Risk assessment to model encounter rates between large whales and vessel traffic from offshore wind energy on the Atlantic OCS. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 85 p. Obligation No.: 140M0119F0033. Report No.: OCS Study BOEM 2021-034.
Population viability analysis and extinction risk tool for NARWs	Develop a population viability analysis that will allow NMFS to characterize the North Atlantic right whale extinction risk, taking into account current and future threats, and determine how much improvement to present-day mortality and reproduction schedules is needed to improve population trajectories.	NOAA NMFS	R. Pace	Runge M, Garrison L, Hostetler J, Knowlton A, Lesage V, Linden D, Williams R, Borggaard D. On-going study. Population viability analysis and extinction risk tool for NARWs. NOAA Fisheries, Northeast Fisheries Science Center. A tool for assessing extinction risk under current demographic rates (as indicated by recent history) and potential scenarios where management measures or environmental conditions change the rates and the resulting population trajectories. 2018–2022 for phase 1. Additional work in phase 2 expected for 2023 and beyond .
Standardizing Integrated Ecosystem-Based Assessment Nationally	Develop a consistent national framework by adapting existing dynamic modeling frameworks to advance integrated environmental assessments at multiple spatial and temporal scales, and account for diverse objectives, drivers, and stakeholders' priorities.	Blue World Research Institute, Inc.	L. Kaufman	Ongoing. Levenson J et al. 2022. Standardizing integrated ecosystem-based assessment nationally (NT-21-x15) https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/Standardizing-Integrated-Ecosystem-Based-Assessment-Nationally.pdf

Table C-11. Studies on detecting and assessing biological impacts

Project Title	Project Objective	Organization	PI or Lead	Reference
A Parametric Analysis and Sensitivity Study of the Acoustic Propagation for Renewable Energy Sources and Projects	Standardize modeling for sound propagation from activities associated with offshore renewable energy development with a focus on pile driving.	CSA Ocean Sciences Inc.	K.D. Heaney	Heaney KD, Ainslie MA, Halvorsen MB, Seger KD, Müller RAJ, et al. (CSA Ocean Sciences Inc, Stuart, FL). 2020. A parametric analysis and sensitivity study of the acoustic propagation for renewable energy sources. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 186 p. Obligation No.: M17PD00003. Report No.: OCS Study BOEM 2020-011.
A systematic review on the behavioral responses of wild marine mammals to noise: the disparity between science and policy	A systematic literature review and analysis to assess the probability and severity of marine mammal behavioral responses to marine sound.	Fisheries and Oceans Canada	C. Gomez	Gomez C, Lawson JW, Wright AJ, Buren AD, Tollit DJ, Lesage VS. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Can J Zool. 94(12):801-819. [accessed 26 May 2023]; https://doi.org/10.1139/cjz-2016-0098
A three-dimensional underwater sound propagation model for offshore wind farm noise prediction	Create a three-dimensional underwater sound propagation model with realistic ocean environmental conditions to assess the sound impacts from offshore wind farm facilities and discuss other applications of soundscape prediction, planning, and management	Woods Hole Oceanographic Institute	Y-T Lin	Lin Y-T, Newhall AE, Miller JH, Potty GR, et al. 2019. A three-dimensional underwater sound propagation model for offshore wind farm noise prediction.. J Acoust Soc Am. 145(5): EL335–EL340. [accessed 31 May 2023]; https://doi.org/10.1121/1.5099560
A Framework for Studying the Effects of Offshore Wind Development on Marine Mammals and Turtles	Summarize the results of a workshop that created a framework aimed at identifying ways to assess population-level impacts of offshore wind facilities on marine mammals and sea turtles	Massachusetts Clean Energy Center	S.D. Kraus	Kraus SD, Kenney RD, Thomas L (New England Aquarium, Boston, MA; University of Rhode Island, Narragansett, RI; Centre for Research into Ecological and Environmental Modeling, St Andrews, UK). 2019. A framework for studying the effects of offshore wind development on marine mammals and turtles: final report. Sterling (VA) and Boston (MA): US Department of the Interior Bureau of Ocean Energy Management and Massachusetts Clean Energy Center. [accessed 31 May 2023]; https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Renewable-Energy/Northeast-Large-Pelagic-Survey-Collaborative-Aerial-and-Acoustic-Surveys-for-Large-Whales-and-Sea-Turtles.pdf

Project Title	Project Objective	Organization	PI or Lead	Reference
Acoustic characteristics from an in-water down-the-hole pile drilling activity	Describe the underwater acoustic characteristics from DTH pile drilling during the installation of 0.84-m shafts within 1.22-m steel piles in Ketchikan, Alaska	BOEM	S. Guan	Guan S, Brooken T, Miner R. 2022. Acoustic characteristics from an in-water down-the-hole pile drilling activity. J Acoust Soc Am. 151(1): 310. [accessed 26 May 2023]; https://doi.org/10.1121/10.0009272
Alternative monitoring systems to explore marine wildlife monitoring at the Revolution Wind offshore wind project	Explore maritime wildlife monitoring and seabed surveillance services for Ørsted and Eversource's upcoming Revolution Wind offshore wind project, especially using alternative monitoring systems to obtain additional flexibility for construction and operation activities.	ThayerMahan, Ørsted, Eversource	C. Stoker	On-going study. Stoker C, Pretyman C. 2020. Ørsted and Eversource partner with Groton Maritime Automation Technology Developer. Ørsted North America News. [accessed 2022 April 25]; https://us.orsted.com/news-archive/2020/01/orsted-and-eversource-partner-with-groton-maritime-automation-technology-developer
Approaches to Understanding the Cumulative Effects of Stressors on Marine Mammals	(1) assess current methodologies for evaluating the cumulative effects of stressors on marine mammals, (2) identify new approaches that could improve assessments, discuss ways to quantify changes in the behavior, health, or body condition, (3) recommend future research initiatives	NAS	NAS	NAS [National Academies of Sciences, Engineering, and Medicine]. 2017. Approaches to understanding the cumulative effects of stressors on marine mammals. Washington (DC): National Academies Press. [accessed 31 May 2023]; doi: https://doi.org/10.17226/23479.
Assessing Environmental and Biological Drivers of North Atlantic Right Whale Abundance and Distribution in New York and the Southern New England Shelf	Assess and quantify spatio-temporal dynamics of zooplankton in waters of the Sunrise Wind Farm area, and integrate zooplankton data into habitat models for North Atlantic Right Whales to improve predictions of NARW in wind energy areas in both space and time	Stony Brook University	J. Warren and L. Thorne	On-going study. Stony Brook University. 31 January 2022. News from Somas: assessing environmental and biological drivers of North Atlantic right whale abundance and distribution in New York and the Southern New England Shelf. Stony Brook (NY): Stony Brook University School of Marine and Atmospheric Sciences. [accessed 2022 April 25]; https://you.stonybrook.edu/somas/2022/01/31/january-2022-news-from-somas/

Project Title	Project Objective	Organization	PI or Lead	Reference
Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals	Measure pile-driving sound at various distances from a wind farm in NE Scotland	University of Aberdeen	H. Bailey	Bailey H, Senior B, Simmons D, Rusin J, Picken G, et al. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Mar Pollut Bull. 60(6):888–897.
Atlantic Marine Conservation Society (AMSEAS) Seal Tagging	Assess the habitat usage of harbor and gray seals in southern New England waters and the New York Bight, including OSW project areas	AMSEAS	R. DiGiovanni	On-going study. NYSERDA [New York State Energy Research and Development Authority]. 2021a. NYSERDA Environmental and Fisheries Mitigation Plans–Sunrise Wind. Slide 40: Atlantic Marine Conservation Society (AMSEAS) Seal Tagging - PI: Rob DiGiovanni. Albany (NY):NYSERDA. [accessed 31 May 2023]; https://www.nyftwg.com/wp-content/uploads/2021/08/20210817_ETWG-FTWG_Sunrise_Wind_Mitigation_Slides.pdf
Behavioral Response of Humpback Whales to Vessel Traffic	Study behavioral responses of marine mammals to ships will to determine the risk of ship strike injury and the disturbance in a high-mortality area.	Duke University, US Navy HDR	J. Shearer	Shearer J, Nowacek D, Swaim Z, Foley H, Janik V, Read A. 2019. Behavioral responses of humpback whales (Megaptera novaeangliae) to approaching ships in Virginia Beach, Virginia, USA. 2019 World Marine Mammal Conference; Barcelona, Spain. Poster ID: 329. Durham (NC): Duke University Marine Lab.
Best Management Practices Workshop for Atlantic Offshore Wind Facilities and Marine Protected Species. Workshop Summary Report	(1) increase understanding of the science and regulations for protecting marine species from the effects of offshore wind development on the Atlantic OCS, (2) understand the perspectives of stakeholder groups on protected species mitigation and monitoring, (3) identify and discuss the best approaches for BMPs to avoid, minimize, and monitor the effects of offshore wind activities on marine protected species.	BOEM	BOEM	Kearns & West (Washington, DC). 2018. Summary report: best management practices workshop for Atlantic offshore wind facilities and marine protected species (2017). Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. Obligation No.: D13PC00174. Report No.: OCS Study BOEM 2018-015.

Project Title	Project Objective	Organization	PI or Lead	Reference
Characteristics of the soundscape before and after the construction of the Block Island Wind Farm	Record and compare the soundscape before and after the development of Block Island Windfarm offshore Rhode Island	Woods Hole Oceanographic Institute	A. Tripathy	Tripathy A, Miller J, Potty G, Amaral J, Vigness-Raposa, et al. 2018. Characteristics of the soundscape before and after the construction of the Block Island Wind Farm. J Acoust Soc AM. 144(3):1856.
Characterization of impact pile driving signals during installation of offshore wind turbine foundations	Analyze acoustic data collected during the construction of the Block Island Wind Farm, the first offshore wind farm in U.S. coastal waters.	University of Rhode Island	J. Amaral	Amaral JL, Miller JH, Potty GR, Vigness-Raposa KJ, Frankel AS, et al. 2020b. Characterization of impact pile driving signals during installation of offshore wind turbine foundations. J Acoust Soc Am. 147:2323–2333.
Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany	Use generalized, additive modeling to investigate the disturbance effects of offshore windfarm construction on harbor porpoises using acoustic porpoise monitoring data and sound measurements during construction of the first 7 large-scale offshore wind farms in the German Bight.	Aarhus University	M. Brandt	Brandt MJ, Dragon AC, Diederichs A, Bellman MA, Wahl V, et al. 2018. Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. Mar Ecol Prog Ser. 596:213-232. https://doi.org/10.3354/meps12560
Ecosystem And Passive Acoustic Monitoring (ECO-PAM) Project.	(1) research for detection of North Atlantic right whale, (2) better understand their presence, distribution and seasonality, (3) contribute to characterization of their habitat in offshore wind lease areas in Ørsted lease areas in New Jersey Massachusetts	Ørsted Wind, Rutgers University, Woods Hole Oceanographic Institute	J. Kohut, J. Brodie, M. Baumgartner	On-going study. Orsted-eco-pam-web-portal.srv.axds.co. c2020-2022. Ecosystem And Passive Acoustic Monitoring (ECO-PAM) Project. Ørsted: A partnership between Ørsted Wind, Rutgers University, and Woods Hole Oceanographic Institute. [accessed 2022 April 25]. https://orsted-eco-pam-web-portal.srv.axds.co/access-data .

Project Title	Project Objective	Organization	PI or Lead	Reference
Effects of Offshore Pile Driving on Harbour Porpoise Abundance in the German Bight	Analyze the construction effects of eight offshore wind farms within the German North Sea on harbor porpoises through a combination of PAM using historical data from Porpoise Detectors and aerial surveys which collected sound levels and other piling characteristic data	IFAO	M. Brandt	Brandt MJ, Dragon AC, Diederichs A, Schubert A, Kosarev V, et al. 2016. Effects of offshore pile driving on harbour porpoise Abundance in the German Bight: assessment of noise effects, final report. Hamburg (DE): Hamburg: Offshore Forum Windenergie.
Harbour porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea	Study whether harbor porpoise occurrence has been affected by the presence of the Dutch offshore wind farm Egmond aan Zee by studying acoustic activity of porpoises in the wind farm and in two reference areas using stationary acoustic monitoring prior to construction and during normal operation of the wind farm.	IMARES Department of Ecosystems	M. Scheidat	Scheidat M, Tougaard J, Brasseur S, Carstensen J, Petel TV, et al. 2011. Harbour porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea. Environ Res Lett. 6:025102. doi: 10.1088/1748-9326/6/2/02510
How could operational underwater sound from future offshore wind turbines impact marine life?	Review published sound levels of underwater sound from operational wind farms and evaluate if and how sound levels change with increasing wind turbines size.	DHI Group	U. Stöber	Stöber U, Thomsen F. 2021. How could operational underwater sound from future offshore wind turbines impact marine life? J Acoust Soc Am. 149(3):1791. doi: 10.1121/10.0003760
How loud is the underwater noise from operating offshore wind turbines?	(1) address the possible influence of turbine size on radiated underwater sound by reviewing the available literature on turbine sound measurements and make these measurements more available, (2) update assessments of offshore wind farms impact on the underwater soundscape and possible effects on the marine environment	Aarhus University	J. Tougaard	Tougaard J, Hermannsen L, Madsen PT. 2020. How loud is the underwater noise from operating offshore wind turbines? J Acoust Soc Am. 148: 2885–2893. https://doi.org/10.1121/10.0002453

Project Title	Project Objective	Organization	PI or Lead	Reference
Individual right whales call louder in increased environmental noise	Investigate the changes in calling behavior of individual endangered North Atlantic right whales when background sound is increased.	Pennsylvania State University	S.E. Parks	Parks SE, Johnson M, Nowacek D, Tyack PL. 2011. Individual right whales call louder in increased environmental noise. Biol Lett. 7(1): 33–35. https://doi.org/10.1098/rsbl.2010.0451
Measurements and Spatial Distribution Simulation of Impact Pile Driving Underwater Noise Generated During the Construction of Offshore Wind Power Plant Off the Southwest Coast of Korea	Measure underwater sound generated by impact pile driving the construction of an offshore wind farm in and predict the spatial distribution of impact pile driving sound by modeling	Korea Polar Research Institute	D-G Han	Han D-G, Choi JW. 2022. Measurements and spatial distribution simulation of impact pile driving underwater noise generated during the construction of offshore wind power plant off the southwest coast of Korea. Front Mar Sci . vol. 8. [accessed 26 May 2023]; https://doi.org/10.3389/fmars.2021.654991
Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic—evidence of slow recovery	Investigate impact on harbor porpoises over more than 10 years at the first large scale offshore wind farm in the world using acoustic porpoise detectors and modified statistical BACI design to detect changes in porpoise presence before, during, and after wind farm construction.	Aarhus University	J. Teilmann	Teilmann J, Carstensen J. 2012. Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic—evidence of slow recovery. Environ Res Lett. 7(4):045101. doi 10.1088/1748-9326/7/4/045101
Observing Cable Laying and Particle Settlement During the Construction of the Block Island Wind Farm	Investigate real-time measurements of seafloor sediment suspension during the construction and operation of the first facilities to be built at Block Island, Rhode Island	BOEM	J. Elliot	Elliott J, Smith K, Gallien DR, Khan A (HDR, Englewood, CO). 2017. Observing cable laying and particle settlement during the construction of the Block Island Wind Farm. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management.. Obligation No.: M15PC00002. Report No.: OCS Study BOEM 2017-027. 226 p. [accessed 26 May 2023]; https://espis.boem.gov/final%20reports/5596.pdf
Particle motion measured at an operational wind turbine in relation to hearing sensitivity in fish	Develop and field-trial a new instrument that measures particle motion and to increase the number of studies investigating the effect of particle motion on fish hearing sensitivity.	Stockholm University	P. Sigray	Sigray P, Andersson MH. 2011. Particle motion measured at an operational wind turbine in relation to hearing sensitivity in fish. J Acoust Soc Am. 130, 200-207. https://doi.org/10.1121/1.3596464

Project Title	Project Objective	Organization	PI or Lead	Reference
Propagation Characteristics of High-Frequency Sounds Emitted During High-Resolution Geophysical (HRG) Surveys: Open Water Testing	Characterize high frequency acoustic sources typically used for geophysical surveys, and to ensure that acoustic propagation and impact models reliably predict the sound field to allow better assessment of potential acoustic impacts to marine fauna	CSA Ocean Sciences, Inc	M. Halvorsen	Halvorsen MB, Heaney KD. (CSA Ocean Sciences Inc, Stuart, FL) 2018. Propagation characteristics of high-resolution geophysical surveys: open water testing. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 806 p. Obligation No.: M15PC0001. Report No.: OCS Study BOEM 2018-052. [accessed 26 May 2023]; https://espis.boem.gov/final%20reports/BOEM_2018-052.pdf
Quieting Technologies for Reducing Noise During Seismic Surveying and Pile Driving Workshop Summary Report. OCS Study BOEM 2014-061	Examine current and emerging technologies that have the potential for reducing sound generated during geological and geophysical exploration, pile driving, and support vessel operational activities	CSA Ocean Sciences Inc.	CSA Ocean Sciences Inc.	CSA Ocean Sciences Inc (Stuart, FL). 2014. Quieting technologies for reducing noise during seismic surveying and pile driving workshop. Summary report. Herndon (VA): US Department of the Interior, Bureau of Ocean Energy Management. 306 p. Obligation No.: M12PC00008. Report No.: BOEM 2014-061.
Real-time Opportunity for Development Environmental Observations (RODEO)	Take real-time measurements of such things as air quality, underwater sound, seafloor sediment suspension during the construction and operation of the first facilities to be built at Block Island, Rhode Island	HDR Environmental, Operations and Construction, Inc. and BOEM	M. Boatman	Boatman M. 2019. Real-time Opportunity for Development Environmental Observations (RODEO) study profile. Sterling (VA): Department of the Interior, Bureau of Ocean Energy Management. 6 p. https://opendata.boem.gov/BOEM-ESP-Ongoing-Study-Profiles-2018-FYQ2/BOEM-ESP-AT-14-01.pdf
Review of offshore wind farm impact monitoring and mitigation with regard to marine mammals	Review the findings and lessons learned from 19 UK and 9 other European Union (EU) offshore wind farm (OWF) developments with regard to sound impact on marine mammals Monitoring and mitigation reports	Sea Mammal Research Unit	U.K. Verfuss	Verfuss UK, Sparling CE, Arnot C, Judd A, Coyle M. 2016. Review of offshore wind farm impact monitoring and mitigation with regard to marine mammals. Adv Exp Med Biol. 875:1175-82. doi: 10.1007/978-1-4939-2981-8_147.
Stony Brook Thermal Camera Marine Mammal Automated Detection Project	Develop standards and evaluate the autodetection capability of thermal camera systems for detecting marine mammals at platforms associated with offshore wind development, construction and operation.	Stony Brook University	A. Borowicz and L. Thorne	On-going study. NYSERDA [New York State Energy Research and Development Authority]. 2021b. NYSERDA Environmental and Fisheries Mitigation Plans – Sunrise Wind. Slide 42: Stony Brook Thermal Camera Marine Mammal Automated Detection Project - PIs: Dr. Alexander Borowicz; Dr. Lesley Thorne. Albany (NY):NYSERDA. [accessed 31 May 2023]; https://www.nyftwg.com/wp-content/uploads/2021/08/20210817_ETWG-FTWG_Sunrise_Wind_Mitigation_Slides.pdf

Project Title	Project Objective	Organization	PI or Lead	Reference
Syracuse University Baleen Whale Acoustic Ecology	Advance the understanding of baleen whale acoustic ecology and the impacts of underwater sound and also advance analytical techniques that will enhance the application of acoustic monitoring for offshore wind development needs	Syracuse University	S. Parks	On-going study. NYSERDA [New York State Energy Research and Development Authority]. 2021c. NYSERDA Environmental and Fisheries Mitigation Plans – Sunrise Wind. Slide 43: Syracuse University Baleen Whale Acoustic Ecology PI: Dr. Susan Parks. Albany (NY):NYSERDA. [accessed 31 May 2023]; https://www.nyftwg.com/wp-content/uploads/2021/08/20210817_ETWG-FTWG_Sunrise_Wind_Mitigation_Slides.pdf
The Effects of Ship Noise on Marine Mammals—A Review	(1) give an overview of literature on the effects of vessel sound on marine mammals and the patchy coverage of species, habitats, vessel types, and types of impact investigated, (2) identify knowledge gaps, explain the concepts of vessel sound generation and propagation	Curtin University	C. Erbe	Erbe C, Marley SA, Schoeman RP, Smith JN. 2019. The effects of ship noise on marine mammals—a review. Front Mar Sci. vol. 6. 11 October. https://doi.org/10.3389/fmars.2019.00606
The underwater sound field from impact pile driving and its potential effects on marine life	Review of how sound from pile driving activities propagates underwater and a summary of literature trying to understand the effects on marine life	University of Washington Seattle	P.H. Dahl	Dahl PH, de Jong CAF, Popper AN. 2015. The underwater sound field from impact pile driving and its potential effects on marine life. Acoust Today. 11(2):18–25.
The underwater sound from offshore wind farms	Summarize the sources, amplitude, and frequency of sounds generated during off shore wind farm construction and operation and review their effects on marine mammals	Marine Acoustics Inc	J. Amaral	Amaral J, Vigness-Raposa K, Miller JH, Potty GR, Newhall A, et al. 2020. The underwater sound from offshore wind farms. Acoust Today. 16(2):13–20. https://doi.org/10.1121/AT.2020.16.2.13
Understanding the population consequences of disturbance	Review applications of a conceptual framework that assesses and predicts population-level consequences of human disturbance on marine mammals, identify research gaps, and explore which models are appropriate for these analyses.	Washington State University	E. Pirotta	Pirotta E, Booth CG, Costa DP, Fleishman E, Kraus SD, et al. 2018a. Understanding the population consequences of disturbance. Ecol Evol. 8: 9934–9946. https://doi.org/10.1002/ece3.4458

Project Title	Project Objective	Organization	PI or Lead	Reference
Using aerial surveys to detect displacement of whales during wind energy construction	Use aerial surveys to detect displacement of whales during wind energy construction	RWSC	L. Scott-Hayward	Scott-Hayward L, Thomas L, Ganley L, O'Brien O, Pendleton D, et al. 2021. Using aerial surveys to detect displacement of whales during wind energy construction. Available from the RWSC (https://neoceanplanning.org/rwse/) or the authors (e.g., L.Scott-Hayward, Centre for Research into Ecological and Environmental Modelling, University of St Andrews, St Andrews, Fife, KY16 9LZ, United Kingdom).

Table C-12. Mitigation studies

Project Title	Project Objective	Organization	PI or Lead	Reference
A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish waters	Review available underwater sound abatement systems for their applicability for pile-driving operations at OWF construction in Scottish waters in preparation for the development of offshore wind farms in Scotland.	Scottish Natural Heritage	U.K. Verfuss	Verfuss UK, Sinclair RR, Sparling CE (SMRU Consulting, St Andrews, UK). 2019. A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish waters. Scottish Natural Heritage. Project No: 017224. Research Report No. 1070.
Bubble curtain effectiveness during impact pile driving for monopile installation at the Coastal Virginia Offshore Wind project	Characterize the effectiveness of bubble curtains at attenuating sound levels by measuring the acoustic field generated by monopile driving before and after curtain installation.	Marine Acoustics Inc	J. Amaral	Amaral JL, Frankel AS, Miller JH, Potty G. 2020a. Bubble curtain effectiveness during impact pile driving for monopile installation at the Coastal Virginia Offshore Wind project. J Acoust Soc Am. 148: 2627 https://doi.org/10.1121/1.5147308
Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises	Study the effects of constructing the DanTysk offshore wind farm by passive acoustic monitoring of pile driving sound and harbor porpoise echolocation.	Aarhus University	M. Dähne	Dähne M, Tougaard J, Carstensen J, Rose A, Nabe-Nielsen J. 2017. Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. Mar Ecol Prog Ser. 580:221–237.
Population viability analysis and extinction risk tool for NARWs	Develop a population viability analysis that will allow NMFS to characterize the North Atlantic right whale extinction risk, taking into account current and future threats, and will allow inquiry into how much improvement to present-day mortality and reproduction schedules is needed to improve population trajectories.	NOAA NMFS	R. Pace	Runge, M., Garrison, L., Hostetler, J., Knowlton, A., Lesage, V., Linden, D., Williams, R., Borggaard, D. On-going study. Population viability analysis and extinction risk tool for NARWs. NOAA Fisheries, Northeast Fisheries Science Center.
Noise Mitigation During Pile Driving Efficiently Reduces Disturbance of Marine Mammals	Acoustically monitor porpoises to determine if using a bubble curtain during construction of the Borkum West 2 wind farm reduced sound disturbance.	BioConsult SH GmbH & Co.KG	G. Nehls	Nehls G, Rose A, Diederichs A, Bellmann M, Pehlke H. 2016. Noise mitigation during pile driving efficiently reduces disturbance of marine mammals. Adv Exp Med Biol. 2016;875:755-62. doi: 10.1007/978-1-4939-2981-8_92. PMID: 26611029

Project Title	Project Objective	Organization	PI or Lead	Reference
The use of an air bubble curtain to reduce the received sound levels for harbor porpoises (Phocoena phocoena)	Measure and quantitatively compare the sound attenuated by a bubble curtain during pile driving at a Denmark windfarm.	Christian-Albrechts-Universität	K. Lucke	Lucke K, Lepper PA, Blanchet M-A, Siebert U. 2011. The use of an air bubble curtain to reduce the received sound levels for harbor porpoises (*Phocoena phocoena*). J Acoust Soc Am. 130(5):3406–3412. https://doi.org/10.1121/1.3626123
Whale Alert Project	Refine the Whale Alert System to prevent lethal ship strikes	Whale Alert Project	L. Burm	On-going study. Burm L. 10 April 2018. Bay State Wind plans more than $2 million in environmental research grants. Ørsted North America News. [accessed 2022 April 25]; https://us.orsted.com/news-archive/2018/04/bay-state-wind-plans-more-than-2-million-in-environmental-research-grants
Wind Energy and Wildlife Interactions	(1) review existing and tested sound mitigation systems and discuss the measured data and influencing factors on the resulting sound reduction, (2) measure the combination of two or more sound mitigation systems during the construction phase to investigate the effect of multiple mitigation systems on emitted sound.	Institute of Technical and Applied Physics GmbH	M. Bellmann	Bellmann MA, Schuckenbrock J, Gündert S, Michael M, Holst H, Remmers P. 2017. Is there a state-of-the-art to reduce pile-driving noise? In: J. Köppel (ed.), Wind energy and wildlife interactions: presentations from the CWW2015 Conference. Cham (CH): Springer International. p. 161-172. https://doi.org/10.1007/978-3-319-51272-3_9

Appendix D: Exposure and Consequence Models for Marine Mammals

Table D-1. Exposure and consequence models for marine mammals

Source: Southall et al. 2021

Model	Developer	Purpose	Animal-Focused	Parameters Used	Ind. Effects	Pop. Effects	Multiple Stressor Effects	Uncertainty
Acoustic Integration Model (MIA), Marine Mammal Mitigation Decision Aid (M3DA)	Marine Acoustics, Inc.	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, can consider avoidance	Yes	No	TBD	No
Marine Mammal Movement and Behavior (3MB)	Marine Mammal Foundation	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, can consider avoidance	Yes	No	TBD	No
JASCO Animal Simulation Model including Noise Exposure (JASMINE)	JASCO Applied Sciences	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, can consider avoidance	Yes	No	TBD	No
MIKE	DHI	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, can consider avoidance, expanded habitat parameters	Yes	No	TBD	No
NAVY Acoustic Effects Model (NAEMO)	U.S. Navy	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, wind speed, can consider avoidance	Yes	No	TBD	No
Agent Seal	Sea Mammal Research Unit (SMRU)	Exposure estimates, impact assessments	Yes	Individual movements, depth, can consider avoidance, expanded habitat parameters	Yes	Yes	TBD	No

Model	Developer	Purpose	Animal-Focused	Parameters Used	Ind. Effects	Pop. Effects	Multiple Stressor Effects	Uncertainty
Interim Population Consequences of Disturbance model (iPCoD)	SMRU Consulting	Impact assessments	No	Range of species parameters	No	Yes	No	No
DEPONs	Aarhus University	Exposure estimates, impact assessments	Yes	Individual movements, hearing capability, depth, sound profile, can consider avoidance, expanded habitat parameters	Yes	Yes	TBD	No
Population Consequences of Exposure to Multiple Stressors (PCoMS)	SERDP	Impact assessments	No	Range of species parameters, multiple stressors	No	Yes	Yes	No
Risk Assessment	Southall et al.	Impact assessments	No	Noise focused, multiple stressors	Yes	Yes	Yes	Yes
Energetics Models	Multiple	Impact assessments	No	Range of species parameters	Yes	Yes	TBD	Yes

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DOI protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

BOEM’s mission is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM’s Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).