Marine Mammals Workgroup Report

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

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Disclaimer

Additional Information

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

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Contents

Background

The 2020 State of the Science Workshop, hosted by the New York State Energy Research and Development Authority (NYSERDA), was held virtually on November 16-20, 2020. The aim of the workshop was to assess the state of the knowledge regarding offshore wind development's potential cumulative impacts on wildlife populations and ecosystems. This workshop brought together over 430 stakeholders engaged with environmental and wildlife research relevant to offshore wind energy development. Attendees included a wide range of stakeholders from offshore industry, government agencies, non-profit organizations, and academia. More information can be found at http://nyetwg.com/2020-workshop.

Following the plenary sessions in November, workshop attendees formed seven workgroups focusing on benthos, fishes and mobile invertebrates, birds, bats, marine mammals, sea turtles, and environmental change. Workgroups, under the guidance of lead technical experts, met virtually in late 2020 and early 2021 to identify scientific research and coordination needs to improve understanding of cumulative impacts from offshore wind energy development, with a focus area from southern New England to North Carolina. **The goal for each group was to identify a list of studies that could be implemented in the next five years to position the stakeholder community to better understand potential cumulative biological impacts as the offshore wind industry develops in the United States. For this effort, cumulative impacts were defined as interacting or compounding effects across spatiotemporal scales, caused by anthropogenic activities relating to the development and operation of multiple offshore wind energy facilities, that collectively affect wildlife populations or ecosystems** (see call-out box for definitions of "effects" and "impacts").[1] The intended audience for this report encompasses a range of stakeholders including researchers, state and federal agencies, offshore wind energy developers, regional science entities, and potential funding entities who might benefit from a collection of prioritized studies for future funding and planning purposes. The studies identified below should not be interpreted as research that must occur prior to any development activity. Rather, these priorities are intended to inform environmentally responsible development and to provide information toward developing means to minimize cumulative impacts over the long term, and many of these research needs are specifically directed at understanding and measuring effects as the industry progresses.

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

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

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

workgroup members had multiple opportunities over the course of several months to provide written input on earlier drafts of this report. The report indicates a general agreement among workgroup members, unless otherwise noted; where there was stated disagreement among workgroup members on a recommendation in this report, this disagreement is noted in the text. Despite the substantial input and influence of workgroup members on the workgroup reports, final report contents were determined by the technical leads, in some cases with support from an additional small subgroup of experts within the group. More information about the workgroups can be found at http://www.nyetwg.com/2020-workgroups.

The marine mammals workgroup was led by Brandon Southall (President and Senior Scientist, Southall Environmental Associates; Research Associate, University of California Santa Cruz) and Laura Morse (Senior Environment & Permitting Specialist, Ørsted), with technical and logistical support from Kate Williams, Edward Jenkins, and Julia Gulka (Biodiversity Research Institute), and Ashley Arayas and others (Cadmus Group). The workgroup consisted of 88 participants (Appendix A), who met virtually three times in the winter and spring of 2020-2021.

Introduction and Methods

Marine mammals, including baleen whales, odontocetes, and pinnipeds, are some of the most studied taxa in the marine environment of the United States. Relatively extensive baseline studies of distribution and some aspects of behavior have been conducted for a few key species in areas off the U.S. east coast that have been leased for offshore wind (OSW) energy development (e.g., Roberts et al. 2016, Bailey et al. 2018, Salisbury et al. 2018, and others). However, many gaps in knowledge remain about their distributions, populations, and other relevant factors, including both short and long-term responses to human disturbance generally, and construction and operation of OSW facilities specifically. In particular, few data are available on the effects of OSW development on taxa other than harbor porpoises (*Phocoena phocoena*) and some seal species in Europe where OSW development has been concentrated to date. Along the U.S. east coast, a suite of protected marine mammal species is expected to interact with OSW development, including the critically endangered North Atlantic right whale (*Eubalaena glacialis*)[2].

For many marine mammal species, a better understanding of OSW effects is important in order to assess the degree of mitigation that may be needed. Following discussion of four conceptual frameworks and previous research efforts for developing strategic plans for understanding and mitigating cumulative impacts to marine mammals (Chief of Naval Operations Energy & Environmental Readiness Division 2013; Kraus et al. 2019; Sandia National Laboratories 2020; NSB Shell Baseline Studies Program 2021[3]), the workgroup adapted several of these approaches and identified four overarching research areas for further discussion:

- **Occurrence:** basic information on the distribution, abundance, and temporal habitat use of species, including seasonal and interannual variability and elements of behavioral ecology (e.g., whether areas are used for feeding, mating, or as a migratory corridor), movement ecology (including baseline diving and surfacing behaviors), and acoustic ecology.

[2] The term "critically endangered" is used in the International Union for Conservation of Nature (IUCN)'s red list of threatened species (https://www.iucnredlist.org); it is not a term used in the U.S. Endangered Species Act (16 U.S.C. § 1531 et seq.).
[3] North Slope Borough Shell Baseline Studies Program http://www.north-slope.org/departments/wildlife-management/nsb-shell-baseline-studies-program

- **Conditions and stimuli:** information on a host of characteristics of the range of OSW activities that may affect marine mammals, including noise, vessel strike risk, changes to habitat (including electromagnetic fields, changes in physical/oceanographic conditions, etc.), and changes to prey base. For noise, examples include where, when, and how often sources are being used in association with different phases of development, the types and properties of radiated noise conditions, how multiple sources associated with OSW interact with one another to influence local soundscapes, and how sound propagates through the water column to allow determination of received levels and other metrics of interest. For pre-existing conditions (such as vessel activity), focus is on incremental change specifically related to OSW operations; this may also require assessment of baseline conditions. In simplest terms, Occurrence + Conditions = Exposure; however, there may be nuances regarding response (see below) that must also be considered for assessing exposure or predicting risk.
- **Response:** how animals may be influenced by or react to exposure to a stressor, on either acute or long-term time scales. Responses can include measurable changes in behavior (including behavioral responses), individual physical condition, communication or navigation abilities related to noise interference, habitat use, and individual or group responses such as movements over larger spatial scales. Baseline information on behavior (see occurrence) may be required to assess responses.
- **Consequence:** the short- and long-term individual or population-level effects of multiple types of exposures and responses. Understanding of population-level cumulative consequences requires an understanding of demographic effects of individual responses. Consequences may include the long-term effects of modifications to distribution, behavior, social groupings, or/and foraging success and how these changes affect fitness through changes in reproduction, growth or survival.

Definitions of terms and other specifics within this framework are included in Appendix B, including:

- Theme (subcategory within each of the four overarching research areas);
- Taxon and geographic region of focus;
- Spatiotemporal scale and OSW development phase of interest;
- Possible research methods[4];
- Additional relevant information (for example, other ongoing research that the proposed project should directly build from).

Within each of these four categories, workgroup members identified a range of possible research objectives (Appendix C, Table C1[5]). From this list, workgroup members applied specific prioritization criteria and identified the highest priority objectives to address in the next five years via the process outlined in Appendix C and Figure 1. Workgroup members were surveyed to identify priorities for research for each of the three major taxonomic groups (baleen whales, odontocetes, and pinnipeds).

Workgroup members overwhelmingly indicated that baleen whales were the highest priority for research in relation to offshore wind energy development (Appendix C), due to the conservation status

[4] While detailed research methodology is outside the scope of this report, approaches for OSW-related monitoring are described in Integral Consulting Inc (2020) and citations therein. Several of the more common approaches are summarized in Appendix D.

[5] Several objectives listed in Table C1 were not further developed during workgroup discussions, and thus are not listed in the main text of this report.

of many species in this group, as well as the relative lack of information on their potential interactions with OSW development.

Research objectives listed in the body of this report, below, are categorized by[6]:

- **Near-term research needs**
  - Priority Level 1 (highest immediate need)
  - Priority Level 2
  - Priority Level 3
- **Longer-term research needs**

Within each of these categories, objectives are grouped by overarching research area as described above. Further exploration of existing Consequence models (such as Population Consequences of Disturbance, or PCoD, models) and their relevance for OSW is included in Appendix E. Workgroup members also made several recommendations for data standardization and transparency, which are included in Appendix F.

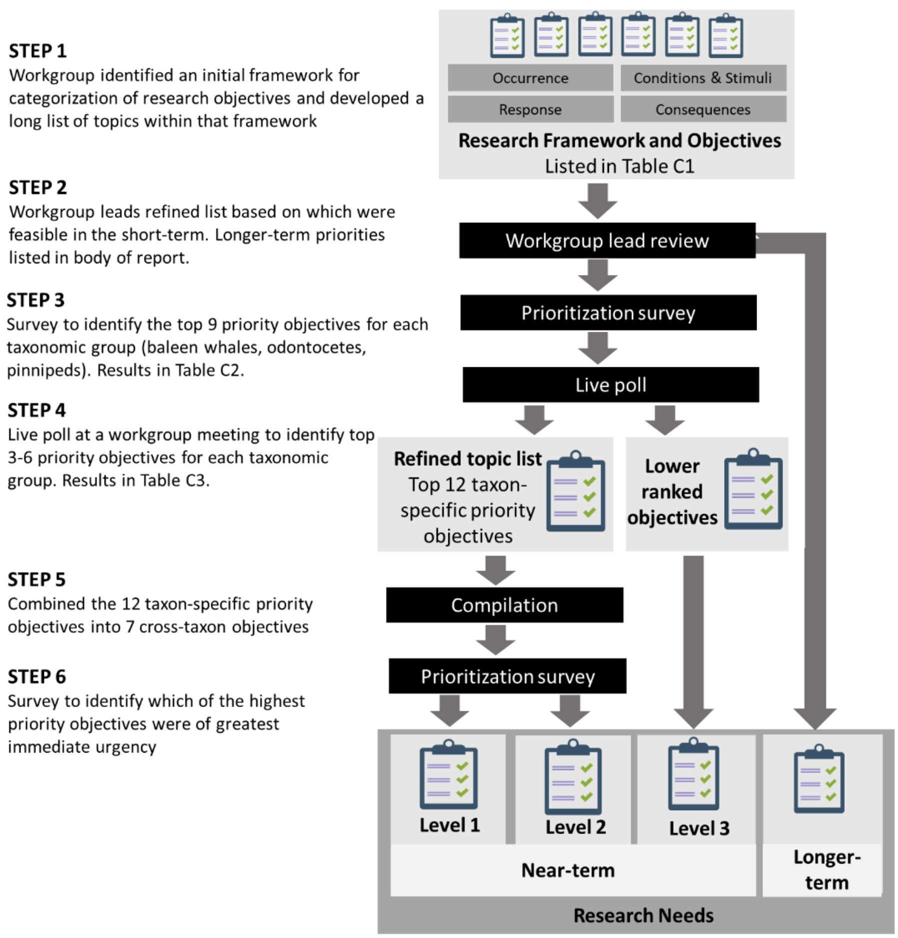

Figure 1. The process used to identify and prioritize short-term research objectives. Following identification of a framework for categorization of research objectives, workgroup members identified a range of possible priority topics within each overarching research area; separated those that seemed feasible on a short-term timeframe (e.g., could be initiated in the next five years) from longer-term objectives; and went through several rounds of prioritization and further elucidation of priority objectives.

[6] Rankings were conducted via qualitative polls of workgroup members. While the ranks of individual research objectives are presented in Appendix C, the authors urge readers to avoid over-interpretation of the relative priority of different objectives. Prioritization criteria and definitions for prioritization categories are discussed in Appendix C.

Short-Term Research Objectives – Priority Level 1

Workgroup members indicated that these topics were the highest immediate priority according to the criteria outlined in Appendix C. Objectives within this section are not listed in any particular order, apart from being grouped by overarching research area. Specific considerations discussed by workgroup members are included for each objective. Workgroup members identified multiple ongoing studies that are relevant to the objectives detailed below; a list of examples is included in Appendix G.

Occurrence Category

Objective: Estimate habitat use, distribution, and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns

Theme: Distribution and abundance, habitat/ecosystem (biological), habitat/ecosystem (physical)

Taxon: Baleen whales, Odontocetes, Pinnipeds

Region: All regions

Spatiotemporal scale: Regional scale, including multiple development sites. Duration should be defined based on specific questions of interest, but will require multiple years for risk assessment models and regulatory assessments. Inter-annual and inter-seasonal variability is informative for understanding consistency of habitat use.

Development phase: All development phases. Assessment of environmental drivers should focus on the pre-construction period (to reduce confounding effects).

Possible methods:

- Multiple data collection and analytical approaches, including visual surveys, dynamic habitat model/hindcasts, artificial intelligence, and telemetry. Studies of presence (see "Determine spatially and temporally explicit species presence in OSW development areas," below) can address portions of this objective, with identified patterns informing future decisions. Some methods such as passive acoustic monitoring (PAM) that are useful for obtaining presence data may also be useful for estimating densities when studies are properly designed for this purpose.
- Need fundamental research on how to combine data from different sources (i.e., visual surveys and PAM). In the short- to medium-term, however, it may be more feasible to develop models (with covariates) from each data source in isolation.
- Environmental variability and environmental changes relating to climate change are real challenges for forecasting, but we need to develop better forecasting capabilities and not just hindcasting, at least on a seasonal level. A broad suite of environmental variables will need to be collected at fine spatial scales to inform distribution and movement models. For example, dynamic habitat models are used to identify environmental variables driving the movement of marine mammals. They require comprehensive data on hydrodynamics (currents, fronts etc.), and additional indicators (e.g., plankton).
- Haul-out surveys and telemetry are key methodological approaches for pinnipeds. Telemetry studies are needed for the collection of baseline habitat use and distribution data, while haul-out surveys are also needed to collect distribution and abundance data for pinnipeds. These can be performed effectively using unmanned aerial vehicles ("drones") as they are relatively

inexpensive, accurate, and can create less disturbance than visual aerial surveys, depending on the altitude at which these are flown. Haul-out surveys may be coupled with aerial surveys of animals in the water for purposes of abundance estimation. Data from tagged seals may also be used to derive correction factors for aerial survey counts. Numbers of animals at haul outs may vary dramatically by day/time of day, so a time series is required.

- Data collection schemas should be standardized and data should be made publicly available to facilitate aggregation of data (Appendix E).

Additional relevant information:

- The Northeast Fisheries Science Center (NEFSC) conducts year-round aerial and shipboard surveys and deploys passive acoustics at numerous sites along the U.S. east coast; the New York Department of Environmental Conservation also conducts winter aerial surveys. The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy are overseeing ongoing telemetry studies using location-only and depth-sensing satellite-tracking tags, as well as acoustic pinger tags that use established underwater receiver arrays. Duke University has a drone lab that may be carrying out seal haul-out surveys on the east coast, and the U.S. Navy and The Nature Conservancy are collaborating on vessel-based haul-out surveys in Virginia, which are facilitated by the use of drones.
- Understanding environmental drivers is key to 1) teasing apart changes due to OSW stressors and those due to environmental variations (e.g., interannual variation and climate change), and 2) investigating potential synergistic effects with other stressors. However, there is not always a clear pattern between environmental covariates and large whale habitat use due to strong influence of learned behavior, traditional use of migration destinations, and other factors.
- Animal telemetry is a valuable tool for monitoring marine mammals at various temporal and spatial scales (Appendix D). The specific tag sensor appropriate for a given monitoring study will depend on the target species and scientific question being asked. There are also trade-offs between tag size and battery life, and tags with multiple sensors capable of collecting high-resolution data are typically more expensive.
- Methodologies to address this objective may in some cases also help to address research priorities identified by other State of the Science Workgroups. In particular, there is potential overlap in the use of visual surveys to understand baseline distributions of sea turtles (Gitschlag et al. 2021) and to assess non-breeding habitat use of seabirds (Cook et al. 2021). Coordinated surveys and data collection networks could help leverage limited resources across taxa.

Expected outcome: Improve understanding of exposure to OSW stressors to inform consequence models.

Objective: Establish individual baseline movements and behavioral patterns (foraging, diving, reproduction, etc.) in OSW development areas

Theme: Behavior

Taxon: Baleen whales, Pinnipeds

Region: All regions

Spatiotemporal scale: Multiple development sites across several years to examine interannual as well as seasonal variability

Development phase: Pre-construction

Possible methods: Tracking, surveys, and dietary analysis. Certain types of telemetry studies are possible for some taxa (e.g., multi-sensor tags that record video, audio, and movement to identify feeding and diet). Scat analysis is also possible with some taxa.

- The densities of prey needed for foraging activity are still poorly understood. We have information for some species but not others, and even for the best-understood species, such as North Atlantic right whale, we still imperfectly understand the processes that lead to foraging activity. Thus, measurements of environmental and prey variables in conjunction with studies of marine mammal movements would be an important dataset, if feasible.
- To investigate pinniped diet and space/habitat use, telemetry (including dive data) should be combined with:
  - Scat sampling at haul-outs to assess fish otoliths, cephalopod beaks and other diagnostic hard remains, as well as fecal DNA analysis to detect prey species without otoliths;
  - eDNA metabarcoding of water samples to examine prey presence/availability (Ruppert et al. 2018).
- To investigate baleen whale space/habitat use, a combination of short-term high-resolution and non-invasive tags (DTAG[7], CATS[8]), medium-term (SMRT[9]) or long-term (SPOT[10]) implantable tags could be used for establishing dive depths, dive and surface durations (to inform collision risk) and spatially-explicit foraging rates. Blow sampling could also be useful for assessment of stress hormones and reproductive state. To investigate baleen whale diet, acoustic measurements of prey density should be combined with:
  - Stable isotope/fatty acid analysis to provide a more complete evaluation of short-term diet composition;
  - An analysis of samples collected from stranded whales (e.g., baleen, earplugs) can provide data on long-term changes in diet composition.

Additional relevant information: Data could inform a variety of animal movement and noise propagation models. Dive behavior could inform cumulative noise exposure and abundance models, for example, and surfacing behavior could inform models of exposure to vessel strike risk. A similar data gap was also recently identified for sea turtles (Gitschlag et al. 2021).

Expected outcome: Improve understanding of exposure to OSW stressors to inform consequence models.

Response Category

Objective: Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment

Theme: Behavioral response (acute)

Taxon: Baleen whales, Odontocetes

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[7] Digital acoustic recording tags https://www.whoi.edu/website/marine-mammal-behavior-lab/dtag
[8] Customized Animal Tracking Solutions https://www.cats.is/
[9] Sound and motion recording and telemetry https://www.onr.navy.mil/reports/FY15/mbjohnso.pdf
[10] Smart Position and Temperature tags https://wildlifecomputers.com/our-tags/spot-argos-satellite-tags/spot/

Region: New England and New York Bight are top priority at present due to current offshore wind development timelines

Spatiotemporal scale: Multiple development sites

Development phase: Construction and operation periods

Possible methods:

- Examine potential acute, individual, or discrete group responses in relation to known or estimated exposure conditions, and identify and measure relevant contextual variables (such as background noise levels and individual-level covariates such as behavioral state). Behavioral response study approaches will be needed; these may be short-term quasi-experimental or informed opportunistic studies (i.e., integrated into short-term monitoring objectives during the construction period).
    - Need to further identify strategic species, locations, and methodological approaches. Sample size will be an issue (hence recommendation to conduct studies at multiple OSW sites, not a single location). More data will be needed from situations with known received noise levels to develop reliable dose-response curves;
    - Need to identify stressor of interest (e.g., pile-driving noise, service vessel noise, etc.).
- Data collection should be combined with spatial modeling (such as animal-focused modeling in combination with dynamic habitat modeling) to simulate response movements for risk assessments. Field data should be used to calibrate and validate models, which in turn can be used to help design better data collection efforts (i.e. sample sizes, parameters).
- Should consider application of adaptable multi-technology studies that can be integrated into actual development activities as components of a short-term monitoring program. Tools include dedicated visual and acoustic observations, individual tagging/telemetry, photo ID, and physiological sampling to examine stress responses (note connection to lower-priority research objective on assessing baseline physiological parameters, below). It will be important to detect behavioral changes (such as changes in feeding behavior) where possible. PAM could also be used, though potential changes in acoustic behaviors would complicate the use of this technology to assess effects.

Additional relevant information: There are existing examples of study designs used to address this type of question, developed largely in relation to Navy sonar (Southall et al. 2019). Note also increasing efforts to integrate and link such studies with population consequences (e.g., Pirotta et al. 2018).

Behavioral responses to sound exposure were also recently identified as a topic of interest for sea turtles (Gitschlag et al. 2021) and fishes and aquatic invertebrates (Popper et al. 2021) as well as marine mammals. In particular, these State of the Science workgroups identified behavioral response studies as a key methodology to examine this question.

Expected outcome: Improve understanding of responses to known or estimated exposure conditions to inform consequence models.

Short-Term Research Objectives – Priority Level 2

In addition to the highest priority (Level 1) short-term objectives identified above, workgroup members indicated that the below objectives are also high priority (Level 2) needs in the short term (as defined using the criteria outlined in Appendix C). Objectives within this section are not listed in any particular order, apart from being grouped by overarching research area.

Occurrence Category

Objective: Determine spatially and temporally explicit species presence in OSW development areas

Theme: Presence

Taxon: Baleen whales, Odontocetes. Specific species/taxa of interest will vary by region.

Region: All regions. Cumulative impact assessments necessitate a larger regional perspective (i.e., entire U.S. east coast), although there is a particular lack of data in the mid- and south Atlantic regions. Likewise, with the exception of North Atlantic right whales, there is a lack of information from Canada (perhaps partly due to issues involving information sharing between researchers/governments), which is problematic as the distribution of key prey items are shifting north.

Spatiotemporal scale: Multiple OSW development sites, including surrounding buffer zones, as well as areas where OSW development-related vessel traffic will occur. Duration should be defined based on specific questions of interest.

Development phase: All development phases (including conducting standardized monitoring studies during pre-construction and operational periods).

Possible methods:

- Data collection needs to be systematic and consistent (across years and seasons). A large-scale gradient design (Methratta 2020) should be used to detect change in presence in relation to regional construction schedules. As data become available, the regional design could/should be modified to more effectively detect potential responses to OSW development activities.
- Need to determine acceptable degree of precision in space/time (i.e., necessary spatial resolution to answer questions). This objective involves determining presence/absence rather than assessing density or abundance, which allows for use of a wider range of data sources. A power analysis should be conducted ahead of any field work to assess power of various methods to detect trends.
- Combination of aerial surveys, PAM, and environmental covariate data. PAM is deployable over long periods and large areas, and is useful for obtaining presence information (work is ongoing to gain density information from acoustic data as well). However, detection distance can be an issue with PAM, and it does not detect animals who are not vocalizing, so visual surveys are also needed. Should stratify by age/sex if possible. New technologies in development that may also be useful include infrared detection systems, autonomous drones in water/air, and detection of whales in satellite imagery.
- There is also a need to consider how to incorporate and/or model other data (i.e., opportunistic observations, Protected Species Observer/Marine Mammal Observer data, citizen science data) which may be able to supplement data collected in directed studies.
- Coordination will be required between developers, scientists, and other users/industries to avoid duplication of effort, integrate research and development activities, and allow for the compilation and aggregation of data across studies.

Additional relevant information:

- A NOAA effort to identify Biologically Important Areas (BIA) for cetaceans is wrapping up this year. The first iteration of this effort was known as the Cetacean Density and Distribution Mapping Working Group (CetMap[11]). The second round of NOAA's BIAs are expected to be released in fall 2021.
- If possible, it would be beneficial to develop criteria for opportunistic yet robust data collection and cooperation with citizen scientists such as fishermen and whale watching vessels.
- Existing data on potential species vulnerability (e.g., data from OSW development in Europe and oil and gas extraction in the Gulf of Mexico that may help indicate which species could be affected by OSW activities) should be paired with distribution data to identify species by region that should be the focus of directed research. For example, due to historic data on sperm whale distributions, this species may be of higher interest in waters off New England than in the South Atlantic Bight.
- Species presence data is valuable to inform some types of mitigation activities (i.e., sharing near-real time data). Siting of future OSW projects, marine spatial planning, and other related activities require more information on abundance and drivers of distributions (see Priority Level 1 Occurrence objectives, above).

Expected outcome: Improve understanding of species' spatiotemporal exposure to OSW stressors to inform consequence models, target further research on habitat use, abundance, and distributions (see "Estimate habitat use, distribution, and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns," above), and inform some types of mitigation activities.

Conditions & Stimuli Category

Objective: Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases

Theme: Exposure (noise)

Taxon: Baleen whales

Region: All regions for large whales (in particular Massachusetts to New York for North Atlantic right whales, and the New York Bight for fin whales [*Balaenoptera physalus*] and humpback whales [*Megaptera novaeangliae*]).

Spatiotemporal scale: Two or more years of baseline studies should be conducted, with additional time if variability in sound levels is found to be high. As sound impact ranges may be large for some species (dozens of km), both lease areas and adjacent areas should be monitored, including areas of current or expected vessel activity, as well as areas with limited or no OSW-related sound.

Development phase: All development phases

Possible methods: A gap analysis to assess what the spatial and temporal extent of expected sound ranges are, followed by a gradient study design to examine power spectral density across a wide

[11] Cetacean and Sound Mapping, NOAA https://cetsound.noaa.gov/important

frequency range (including measurements of frequency, duration, and sound intensity). Passive acoustic methods could include a combination of fixed receivers, towed arrays, and gliders; locations of fixed receivers should be carefully considered relative to possible turbine locations. The study should use standardized protocols and data should be made publicly available. Existing efforts by other groups (e.g., Cornell University, Woods Hole Oceanographic Institution, NOAA, Wildlife Conservation Society) should be leveraged, if possible.

Additional relevant information: This type of information on acoustic baselines could inform our understanding of potential OSW-related exposures for multiple taxa in addition to marine mammals, including fishes and aquatic invertebrates (Popper et al. 2021) and sea turtles (Gitschlag et al. 2021).

Expected outcome: Improve understanding of potential exposure conditions to inform consequence models.

Objective: Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods

Theme: Habitat/ecosystem (biological)

Taxon: Pinnipeds

Region: All regions

Spatiotemporal scale: Year-round at multiple development sites, plus regional monitoring outside of OSW sites.

Development phase: Pre-construction, construction, and operational phases

Possible methods:

- Before-after study design using telemetry for focal marine mammals to examine movements of prey species. OSW-focused studies will need to be placed in the context of larger oceanographic and ecosystem changes (See "Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods," below). Starting monitoring prior to any development activities could be beneficial, and multiple data streams will be needed to understand drivers and consequences.
- Focus in part on assessing prey field by examining species composition, distribution, and abundance, including frequency and abundance of forage fish aggregations. Includes possible effects from artificial reefs and changes in distribution of fishing effort.
- Entanglement is a major threat to pinnipeds (especially for the benthic-foraging grey seal [*Halichoerus grypus*]). Underwater cameras could be used to examine habitat changes that may affect entanglement risks. These could be paired with drone surveys of haul-out areas.
- Both onshore/coastal and offshore components of OSW development may affect pinnipeds, as cable routes may affect haul-out areas. Control sites (whether separate sites or as part of a gradient design) will be required to help disentangle effects of climate change from OSW development.

Additional relevant information:

- There are some related research needs on baseline foraging behavior that may be required first (see "Establish individual baseline movements and behavioral patterns in OSW development areas," above).
- This research objective was consistently identified as a need among other State of the Science workgroups in addition to marine mammals. The State of the Science birds workgroup also identified changes in prey conditions as a priority research topic (Cook et al. 2021). The State of the Science workgroups focused on benthos (Degraer et al. 2021) and on sound-related effects to fishes and aquatic invertebrates (Popper et al. 2021) developed several research questions related to this topic, including the effect of OSW development on 1) habitat use by juvenile fish, 2) spawning habitat, and 3) the distribution of mobile species, all of which could potentially inform understanding of changes for important marine mammal prey species.

Expected outcome: Improve understanding of potential for indirect effects to marine mammals from OSW development via effects on prey populations or habitats.

Response Category

Objective: Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities

Theme: Injury and mortality

Taxon: Baleen whales (with particular focus on North Atlantic right whales and fin whales)

Region: All regions, though New England and New York Bight are first priorities.

Spatiotemporal scale: Multi-year and multi-site vessel strike risk assessment that should include not only OSW development and maintenance-related vessel activities, but also other vessels potentially shifted from OSW areas.

Development phase: All development phases, with a focus on construction and operations

Possible methods:

- Information is needed on possible (localized) changes in marine mammal habitat use related to OSW development, including diving and surfacing behavior, and how those relate to collision risk. Modeling and measurements of changes in vessel patterns (both associated with and not related to OSW activities) will also be needed, and is addressed in another objective ("Evaluate changes in traffic patterns related to OSW activities," below). As noted under that objective, evaluation of vessel strike risk could become an extensive effort due to the need to consider how other types of activities are affected by OSW development (e.g., changes in fishing effort and other traffic patterns).
- In addition to vessel traffic information, addressing this objective requires information on changes in marine mammal distributions and movements as well as an understanding of the factors that influence vessel strike risk. The former can be developed through visual surveys, acoustic monitoring, tagging efforts and modeling of changes in habitat use pre-, during, and post-construction. Dive behavior, movement, and surfacing behavior would also be helpful

parameters to evaluate this risk (see "Establish individual baseline movements and behavioral patterns in OSW development areas," above).

- To better understand other factors that influence vessel strike risk, information is needed including the proportion of populations that are struck, and how severely individuals are affected. National Marine Fisheries Service (NMFS) Stock Assessment Reports[12] and Mortality and Serious Injury Reports[13] provide some information on vessel strikes for large whales but the robustness of this baseline varies by species (the best data exist for North Atlantic right whales, minke whales [*Balaenoptera acutorostrata]*, and humpback whales). It can be challenging to assign mortality to specific sources/industries, and funding will be required to conduct thorough necropsies and tissue sampling of all marine mammal carcasses discovered during OSW development activities. It is also important to note that speed restrictions may be required for most OSW activities (crew transfer vessels are likely to be the most common OSW vessels traveling at high speeds, though other vessels may also travel in excess of 10 knots), so it is probably not reasonable to assume similar strike rates across locations/industries with different mitigation measures in place. Assumptions about OSW mitigation actions should be incorporated into modeling efforts, where possible.

Additional relevant information:

- Some information already exists and has been partially analyzed in Construction and Operations Plans (COPs), Environmental Impact Statements (EISs), Biological Opinions, Biological Assessments, and cumulative impact assessments. Mitigation actions to reduce effects to North Atlantic right whales include vessel speed restrictions and/or additional monitoring measures.
- Coastwide encounter rate risk modeling is ongoing for North Atlantic right whale and other species, but these are based on existing vessel traffic patterns and cannot produce predictions of risk yet.
- A recent study funded by the Bureau of Ocean Energy Management (BOEM; Barkaszi et al. 2021, Malhotra et al. 2021) provides information on the distribution and behavior of vessels during OSW operations and a Vessel Risk Calculator Program[14].
- A better understanding of the risk of OSW-related vessel strike was also recently identified as a need for sea turtles (Gitschlag et al. 2021). In particular, both marine mammal and sea turtle assessments could benefit from an improved understanding of vessel activity patterns and habitat use patterns as they relate to risk.

Expected outcome: Improve understanding of potential risk of vessel strikes to inform consequence models.

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[12] Marine Mammal Stock Assessment Reports by Species/Stock https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock

[13] Marine Mammal Mortality and Serious Injury Reports https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

[14] BOEM Vessel Risk Calculator Program https://www.boem.gov/environment/vessel-risk-calculator-16-setup-105-ocs2021-035

Short-Term Research Objectives – Priority Level 3

In addition to the seven objectives discussed above, a range of additional research needs were identified by workgroup members during discussions. Objectives that were identified but not prioritized or developed in detail during group discussions are included in the full list of objectives in Table C1.

Objectives that were not prioritized in surveys (according to the criteria outlined in Appendix C), but that did warrant additional group discussion and development of ideas, are listed below. In some cases, these objectives were not prioritized due to lower perceived urgency by workgroup members; in other cases, however, otherwise high-priority topics may have been ranked lower due to sequencing of research (e.g., other objectives may need to be addressed first to inform the design or implementation of the needed research). Objectives within this section are not listed in any particular order, apart from being grouped by overarching research area.

Occurrence Category

Objective: Identify baseline vocalization behavior, including seasonality and acoustic characteristics, in OSW development areas

Theme: Behavior

Taxon: All

Region: All regions

Spatiotemporal scale: Multiple development sites across several years, to assess interannual as well as seasonal variability

Development phase: Pre-construction

Possible methods: PAM for basic acoustic characteristics and large-scale seasonal patterns; for vocal behavior that cannot be quantified by PAM alone (source level, call rates, and demographic differences in both), may use towed or GPS-synchronized localization arrays and/or acoustic tags. Tag-based methods, such as high sample rate accelerometers and dual hydrophones, used to identify individual callers to quantify calling rates, and directional/localization capabilities on passive receivers can provide information beyond simple temporal patterns in soundscapes to get at cue rates (calling frequency) and density estimates.

Expected outcome: Improve understanding of pre-development acoustic behaviors to inform interpretation of effects data.

Objective: Establish baseline of physiological parameters such as stress hormones

Theme: Physiology

Taxon: Baleen whales (particular focus: North Atlantic right whale)

Development phase: Pre-construction

Possible methods: Stress hormone studies (breath; biopsy) for living animals. Additional samples of baleen and teeth can be taken from deceased individuals.

Expected outcome: Improve understanding of pre-development physiology to inform interpretation of effects data.

Objective: Examine diet composition and primary prey species, particularly in/near planned OSW areas

Theme: Diet

Taxon: Baleen whales (particular focus: North Atlantic right whale)

Development phase: Pre-construction

Possible methods: Fecal DNA, stable isotope analysis, fatty acid analysis. Samples can be obtained from both free-living and stranded individuals.

Additional relevant information: There is evidence that North Atlantic right whale diet is more varied in southern New England than previously thought. We need a better understanding of diet and prey species so we can develop monitoring plans for prey in the longer term.

Expected outcome: Improve understanding of pre-development diet to inform interpretation of effects data.

Objective: Examine energetic requirements and health condition of individuals, particularly reproductive females

Theme: Health

Taxon: Baleen whales (particular focus: North Atlantic right whale and other endangered species)

Development phase: Pre-construction

Possible methods: Health assessment; blubber thickness measurement (via sonogram); breath; biopsy; photogrammetry; calving interval assessment (photo-id catalog).

Expected outcome: Improve understanding of pre-development energetics and health to inform interpretation of effects data.

Conditions & Stimuli Category

Objective: Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas

Theme: Exposure (noise)

Taxon: Baleen whales, Odontocetes

Region: All regions

Spatiotemporal scale: Year-round at multiple development sites. Sites should include a range of characteristics or conditions that could influence acute noise frequency, duration, or amplitude (e.g., turbine size, foundation type, bottom sediment, conductivity, temperature, depth).

Development phase: All development phases

Possible methods: Studies to examine all noise sources, including helicopter and aircraft. As much as possible, we need to understand source levels and distribution of signal energy across a wide frequency range. Assessments should include examinations of radiated noise characteristics (e.g., sound pressure and sound exposure levels, frequency spectrum, duration) both at the source and over various distances to evaluate noise propagation effects on these parameters (Southall et al. 2021, Southall et al. 2007).

Expected outcome: Improve understanding of potential exposure conditions to inform consequence assessments.

Objective: Evaluate changes in vessel traffic patterns related to OSW activities, including vessel traffic directly associated with OSW as well as potential changes in other traffic patterns in response to OSW development

Theme: Exposure (vessel strike)

Taxon: Baleen whales

Region: All regions

Spatiotemporal scale: Year-round at multiple development sites

Development phase: All development phases

Possible methods: Use Automatic Identification System (AIS) data where possible for information on vessel traffic; there should be AIS data for all OSW vessels. Also need to capture information on non-OSW traffic as well, some of which will have AIS and some won't (e.g., recreational fishing vessels may not have AIS). Need to focus on vessels under 65 ft as well as larger vessel classes. For studying vessels without AIS, it's possible that visual or acoustic surveys could be used. Evaluations of vessel activities (to understand vessel strike risk) could become an extensive effort because of the need to consider non-OSW activities and how those are affected by OSW development (e.g., changes in the location of commercial fishing activities and other traffic patterns).

Additional relevant information:

- Some information already exists and has been partially analyzed in COPs, EISs, Biological Opinions, Biological Assessments, and cumulative impact assessments. Mitigation actions to reduce effects to North Atlantic right whales include vessel speed restrictions and pile-driving schedules.
- Coastwide encounter rate risk modeling is ongoing for North Atlantic right whale and other species, but these are based on current vessel patterns and are not yet able to produce predictions of risk.

- A recent study funded by BOEM (Barkaszi et al. 2021, Malhotra et al. 2021) provides information on the distribution and behavior of vessels during OSW operations and a Vessel Risk Calculator Program[15].
- As mentioned above (see "Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities"), the State of the Science workgroup focused on sea turtles were also interested in understanding vessel traffic patterns (Gitschlag et al. 2021) and how those relate to potential collision risk.

Expected outcome: Improve understanding of potential exposure conditions to help evaluate threat of mortality/injury from vessel strikes (See "Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities," above).

Objective: Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods

Theme: Habitat/ecosystem (physical)

Taxon: N/A

Region: All regions

Spatiotemporal scale: Year-round at multiple development sites, plus regional monitoring outside of OSW sites.

Development phase: Pre-construction and operational periods

Possible methods: Long-term monitoring in and around OSW sites to monitor possible changes in physical and oceanographic features; ecosystem sampling should occur at turbine, wind farm, and regional scales. Efforts should be integrated with the U.S. Integrated Ocean Observing System[16]. Unmanned systems (e.g., slocum gliders) with the capability to take measurements of the water column may be useful. Prey sampling (e.g., continuous plankton recorders, bongo nets) is also important, and is addressed in a separate objective, above ("Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods").

Additional relevant information: Effects on stratification and mixing of the water column have been observed at some OSW facilities in Europe and should be examined in the U.S., particularly with regard to possible effects on prey species for North Atlantic right whales and other taxa of interest. This topic is addressed in more detail in the State of the Science workgroup report on environmental stratification (Carpenter et al. 2021).

Expected outcome: Improve understanding of potential for indirect effects to marine mammals from OSW development via effects on prey populations or habitats.

[15] BOEM Vessel Risk Calculator Program https://www.boem.gov/environment/vessel-risk-calculator-16-setup-105-ocs2021-035
[16] U.S. Integrated Ocean Observing Network https://ioos.noaa.gov/

Response Category

Objective: Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term responses (specifically avoidance or attraction) to OSW development areas

Theme: Behavioral response (chronic)

Taxon: Baleen whales, Pinnipeds

Region: New England and New York Bight as first priorities

Spatiotemporal scale: Seasonal repeated sampling design at multiple OSW sites

Development phase: Pre-construction, construction, and operational phases. Artificial reef effects are an important consideration for the attraction of some species, so operational studies should include relevant timescales to capture the possible occurrence of this phenomenon.

Possible methods: Conduct long-term (months to year) strategic monitoring, including surveys and standardized sampling approaches, over a large area (hundreds to thousands of sq. km), to assess species responses to OSW development. Consider possible energetic consequences or other fitness implications (potentially both positive and negative), and potential for interactive effects (i.e., if attraction or displacement influences potential vessel strike risk). Identify relevant contextual variables including prey resources and habitat factors.

- Integrate multiple methods including dedicated visual and acoustic observations, individual tagging/telemetry, and photo ID. Biopsy sampling could also be useful to assess stress responses, but on longer temporal and spatial scales than some of the above methods. Tagging of seals is relatively easier that other species for longer-term tag deployments.
- Adequate control sites are difficult to find, so use of a gradient design is recommended.
- Studies to better understand prey should be integrated with this study (See "Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods," above).
- An unresolved question is whether to target migratory or resident animals.

Additional relevant information: There are existing examples of approaches to this type of question that have been applied for other species and types of anthropogenic activity (e.g., Thompson et al. 2013).

Expected outcome: Improve understanding of long-term responses to inform risk and consequence assessment.

Objective: To what degree do animals experience potential auditory effects of various types (such as masking, Lombard effect, or Temporary Threshold Shifts)

Theme: Acoustic response

Taxon: Baleen whales, Pinnipeds. These are likely the most relevant taxa given source characteristics (e.g., the low frequency of the sounds in question) and presumed or known hearing capabilities for these taxa.

Region: New England and New York Bight as first priorities

Spatiotemporal scale: Likely includes both short-term and longer-term considerations depending upon effect; masking and Lombard issues (e.g., increases in vocalization volume to compensate for louder surroundings; Hotchkin and Parks 2013) may have more acute manifestation but with longer-term consequences, while temporary threshold shifts (TTS) are likely very rare, localized, and specific to high-intensity construction-related events. Study should possible be conducted at multiple OSW energy sites.

Development phase: All development phases

Possible methods: Passive acoustic methods for evaluating both vocal responses and ambient noise conditions. Specific consideration of frequency bins, species recognition algorithms, and density estimation kinds of methods applicable here.

- Energetic implications of potential Lombard effects or changes in calling rate are relevant (free-ranging animals and likely more relevant to low frequency species);
- Measurements of high-intensity noise events and models of cumulative noise exposure approaches for TTS (limited to captive animal proxies in the case of pinnipeds). Important considerations are source type (impulsive/non-impulsive), duration and patterns of exposure, and frequency spectrum (and effects of mitigation measures including bubble curtains);
- Measurements of TTS onset and increases as a function of sustained exposure ("growth") will inform estimates of injury/permanent threshold shift (PTS; see additional objective below);
- Other considerations: There could be different effects and consequences depending on noise source and species. Communication effects may be relatively minimal at the individual level but may be more commonplace on a broad spatial scale.

Additional relevant information: Many masking models have been developed, but consideration of an animal's capacity to compensate is not always included. Blackwell et al. (2015) is an example of a study on vocal responses in whales. This topic was also identified as a research need for fishes and aquatic invertebrates (Popper et al. 2021).

Expected outcome: Improve understanding of sound-related effects to support development and refinement of risk and consequence assessment.

Objective: Assess physiological/stress consequences of exposure to OSW stressors

Theme: Physiological response, body condition

Taxon: Baleen whales

Region: New England and New York Bight first priority

Spatiotemporal scale: Single or multiple OSW sites. Likely includes both short-term and longer-term considerations depending upon species and activity type (construction with potentially acute responses; operations representing chronic exposure).

Development phase: All development phases

Possible methods: Examine individual habitat use and site fidelity. Use genetics; biopsy; breath; parts; hormone analysis. Should sample body condition as well for possible correlations (photogrammetric measurements). Will be very challenging to link changes in body condition to OSW development vs. other possible causes, however, particularly for animals using multiple foraging grounds.

Additional relevant information:

- More data exist on physiological and stress responses to other types of stressors (e.g., Naval sonar) and species more conductive to these kinds of assessments (e.g., small delphinids) than for OSW or baleen whales.

- Possible link with acute behavioral response studies above ("Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment").

Expected outcome: Improve understanding of physiological responses to OSW stressors to inform risk and consequence assessment.

Objective: Evaluate relative threat of serious injury (PTS) from high-intensity noise exposure associated with OSW and non-OSW activities

Theme: Injury and mortality

Taxon: Baleen whales

Region: New England and New York Bight first priority

Spatiotemporal scale: PTS assessment is about short-term, high intensity, very localized conditions; possibly examine at multiple OSW sites.

Development phase: Construction

Possible methods: Largely modeling studies given inability to study PTS directly in any species. While expected that the risk of PTS from OSW activities is extremely low, bounded modeling exercises to determine probabilities based on spatial/temporal operations could be a relatively straightforward goal.

Additional relevant information: PTS should be considered in relation to TTS assessment objective above ("To what degree do animals experience potential auditory effects of various types (such as masking, Lombard effect, or Temporary Threshold Shifts").

Expected outcome: Improve understanding of sound-related effects to support development and refinement of risk and consequence assessment.

Consequence Category

Objective: Assess individual energetic consequences of behavioral changes due to OSW development activities

Theme: Individual effects

Taxon: Baleen whales (specifically North Atlantic right whales)

Region: Any

Spatiotemporal scale: 1+ years, regional scale

Development phase: All development phases (focus on construction/operations)

Possible methods: GPS tracking (need to be able to distinguish different behavioral states, such as foraging) and modeling. May be worth considering whether to focus on a proxy species for North Atlantic right whales (such as fin whales) to allow quicker development of energetics model.

Additional relevant information: A North Atlantic right whale energetics model is currently in development by Jasmin Hütt and others (J. Hütt, pers. comm.), and it would be beneficial to build off of this existing work and include data specifically on avoidance and other factors related to OSW development. This research objective also ties into other Conditions and Response topics (e.g., habitat displacement and avoidance, behavioral disruption, prey species, diet composition).

Expected outcome: Develop OSW-specific energetics model(s) to inform risk and consequence assessments.

Objective: Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative impacts on moderate and long timescales in OSW areas

Theme: Population effects

Taxon: None provided

Region: None provided

Spatiotemporal scale: Model development should occur within 3-5 years while focus of model is longer timescales (i.e., life of OSW projects). Spatially, this should occur at the regional scale, focusing on OSW sites.

Development phase: All development phases

Possible methods: Develop risk assessment models that incorporate uncertainty, appropriately weight different population, natural history, and other environmental factors, and are holistic, long-term, and robust. These models need to be able to assess current risks as well as future effects, and be adaptable to incorporate new information on effects as it becomes available. A combination of methods and technologies should be used. It may be helpful to start with a focus on understanding the cumulative population effects of a select number of individual stressors on specific behavioral states or life history stages (e.g., foraging, breeding behavior, nursery areas, lactating females) before undertaking more comprehensive cumulative assessment.

Additional relevant information: Build off of Southall et al. (2018) risk assessment framework for Geological and Geophysical surveys in Gulf of Mexico. Other risk assessment frameworks may also be useful to consider (e.g., Heinis and de Jong 2015).

Expected outcome: Develop OSW-specific cumulative impact models to inform risk and consequence assessments.

Longer-Term Priorities

Several objectives, listed below, were judged to be important by workgroup members, but were not thought to be feasible to address in the next 3-5 years.

Objective: Evaluate trends in fitness (survival, reproduction) and abundance for populations that are regularly exposed to OSW stressors

Theme: Population effects

Taxon: Baleen whales, Odontocetes, Pinnipeds

Comments: We rarely have the power to detect population-changes or identify their cause, and certainly not within a 3–5-year period for such long-lived species. However, for some critically endangered species, such as North Atlantic right whale, an individual effect is also a population-level effect.

Objective: Evaluate the consequence of multiple stressors

Theme: Multi-stressor effects

Taxon: North Atlantic right whale

Comments:

- We need to prioritize an adaptive management monitoring framework for listed species under the Endangered Species Act. In the short term we may need to focus on understanding effects of individual stressors, and mitigating them where possible; longer term, incorporating data on multiple stressors into a population consequence model would better support adaptive management. It may also be helpful to consider using indicator species, such as fin whale, in place of North Atlantic right whale.
- An effort to model cumulative impacts on marine mammals is underway by Tyack et al. (the Strategic Environmental Research and Development Program Population Consequences of Multiple Stressors project). This model could be applied once more information is available on OSW effects.

Conclusions

Based in part on the U.S. Navy framework for studies of cumulative impacts (Chief of Naval Operations Energy & Environmental Readiness Division 2013), as well as other relevant frameworks, this workgroup defined four overarching areas of cumulative impact-focused research (occurrence, conditions and stimuli, response, and consequence) that collectively would help to improve the state of knowledge on cumulative impacts from OSW development in the eastern U.S. Marine mammals are some of the most-studied taxa in the marine environment of the U.S., but key gaps remain in our understanding of their distributions, populations, and other relevant factors. Additionally, little is known about the effects of OSW development on taxa other than harbor porpoises and some seal species (based primarily on studies outside the U.S.). These gaps indicate that assessment of consequence (e.g., cumulative impacts to populations) will be a longer-term effort, as is reflected in the "Longer-Term Priorities" defined above. However, addressing the research priorities outlined in this report will situate the OSW, regulatory, and research communities to develop an improved understanding of the potential for cumulative impacts by producing new data to feed into consequence models (e.g., Appendix E).

Workgroup members identified immediate priorities for research for each of the three major taxonomic groups (baleen whales, odontocetes, and pinnipeds); however, the group overwhelmingly indicated that baleen whales were the highest priority for research in relation to OSW development (Appendix C). In addition to this basic assessment of priority by taxonomic group, workgroup members also identified the following needs:

- **A need to better delineate high priority species by region and lease area, based on a combination of exposure (e.g., spatiotemporal distributions) and potential vulnerability to OSW stressors.** For example, some species that could be highly vulnerable may not be common on the U.S. east coast, and thus may be focal taxa of high research interest only when they occur at times and locations that could lead to substantial exposure. Vulnerability to potential effects should be assessed based on a combination of conservation status and existing effects data from other types of offshore industries, among other sources. Workgroup members also noted that vulnerability will likely vary with life history stage (e.g., mother-calf pairs, juveniles), whether animals are resident or primarily transient in areas influenced by OSW development, and the type of stressor being examined.
- **A need for substantial data pre-construction and from areas outside OSW footprints, to reduce uncertainty and assumptions in models.** In particular, the workgroup identified the importance of species presence data in and around OSW development areas, as well as estimation of habitat use, distribution, and abundance by season in and around OSW development areas, during all development phases.
- **A need to identify the dynamic environmental variables driving the above-mentioned patterns in order to interpret the results of OSW effect studies** (e.g., to differentiate the effects of OSW from other sources of natural or human-caused change). It is also important to examine changes in ecosystem and prey conditions more holistically, and consider other taxa and types of stressors. Understanding environmental dynamics and potential changes in resources was also discussed in other State of the Science workgroups (Cook et al. 2021, Gitschlag et al. 2021, Degraer et al. 2021).
- **A need for data standardization and coordination.** Workgroup members strongly advocated for coordination of research, including coordination between developers and independent scientists, as well as other relevant stakeholders, to integrate research efforts and allow for the compilation and aggregation of data across studies. Standardized data collection approaches (Appendix F) and data transparency will also be essential to facilitate aggregation of data and achieve sufficient sample sizes to examine potential effects. For example, much of the same information on nutrition, stress, and prey species that can be gained via biological sampling of live animals can also be analyzed from skin, blubber, baleen, fecal material, and stomach contents from deceased animals through necropsies. This comparison could provide importance data, and therefore it is importance that information is collected consistently. A need for methodological and data standardization and transparency was also noted in other State of the Science workgroups (Carpenter et al. 2021, Cook et al. 2021, Degraer et al. 2021, Hein et al. 2021, Popper et al. 2021).

In waters off of the eastern U.S., a suite of endangered and otherwise protected marine mammal species are expected to interact with OSW development, including the critically endangered North Atlantic right whale. While research to understand the effects of OSW development on individuals and populations is essential, workgroup members noted it may not be the top priority for certain critically imperiled species. Due to their conservation status, many workgroup members noted that an immediate focus on mitigating near-term effects is the highest priority for these species, in addition to monitoring, research, and modeling efforts to improve our understanding of effects. In contrast, for some less-critically endangered species, assessments of the types and severity of OSW-related effects could help tailor the extent and type of possible management or mitigation approaches as they relate to future OSW development activities.

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Appendix A. Workgroup Members

Table A1. Workgroup members who attended one or more workgroup meetings and/or provided written comments on research priorities. Members are listed alphabetically by first name.

Name	Affiliation
Aaron Rice	Cornell University
Alexander Schubert	BioConsult SH GmbH & Co. KG
Amy Scholik-Schlomer	National Marine Fisheries Service
Andrew Johnson	Defenders of Wildlife
Anita Murray	Wildlife Conservation Society
Ann Zoidis	Tetra Tech
Artie Kopelman	Coastal Research and Education Society of Long Island
Bob Kenney	University of Rhode Island Graduate School of Oceanography
Brandon Southall	Southall Environmental Associates Inc.
Caroline Good	National Marine Fisheries Service
Caroline Hoeschle	BioConsult SH
Carter Esch	National Marine Fisheries Service
Chandra Goetsch	Biodiversity Research Institute
Chris Orphanides	National Marine Fisheries Service
Christine Sloan	National Offshore Wind Research and Development Consortium
Christopher Clark	Vineyard Wind
Cormac Booth	SMRU Consulting
Corrie Curtice	Duke University
Cynthia Pyc	JASCO Applied Sciences
Danielle Brown	Gotham Whale
Darren Ireland	LGL Ecological Research Associates, Inc.
Dave Steckler	Mysticetus
David Zeddies	JASCO Applied Sciences
Debi Palka	National Marine Fisheries Service
Dom Tollit	SMRU Consulting
Douglas Nowacek	Duke University
Dusty Miller	Black & Veatch
Ed Jenkins	Biodiversity Research Institute
Elisa Bravo Rebolledo	Bureau Waardenburg
Emily Chou	Wildlife Conservation Society
Emily Hague	Heriot-Watt University
Erik Kalapinski	University of Massachusetts
Francine Kershaw	Natural Resources Defense Council
Frank Thomsen	Danish Hydraulic Institute
Frants Jensen	Woods Hole Oceanographic Institution
Gillian Sutherland	APEM
Greg Silber	Smultea Sciences
Hadley Clark	Woods Hole Oceanographic Institution
Howard Rosenbaum	Wildlife Conservation Society
Jacalyn Toth	Stockton University
Jaclyn Daly	National Marine Fisheries Service
Jacob Levenson	Bureau of Ocean Energy Management
Jason Roberts	Duke University
Jeff Herter	New York Department of State

Name	Affiliation
Jennifer Amaral	Marine Acoustics, Inc.
Jessica Redfern	New England Aquarium
Jonathan Vallarta	SLR Consulting
Judy Dunscomb	The Nature Conservancy
Julia Gulka	Biodiversity Research Institute
Julia Stepanuk	Stony Brook University
Kate McClellan Press	New York State Energy Research and Development Authority
Kate Williams	Biodiversity Research Institute
Kathy Vigness-Raposa	INSPIRE Environmental
Katy Limpert	JASCO Applied Sciences
Kaus Raghukumar	Integral Consulting
Koen Broker	Shell New Energies
Kristen Ampela	HDR, Inc.
Kyle Baker	Bureau of Ocean Energy Management
Laura Ganley	New England Aquarium
Laura Jervis	APEM
Laura Morse	Ørsted
Laura Sliker	Equinor
Lesley Thorne	Stonybrook University
Liz Ferguson	Ocean Science Analytics
Liz Gowell	Ørsted
Louis Brzuzy	Shell New Energies
Mari Smultea	Smultea Sciences
Mark Sullivan	Stockton University
Matt Robertson	Vineyard Wind
Meghan Rickard	New York State Department of Environmental Conservation
Melinda Rekdahl	Wildlife Conservation Society
Melissa Whaling	Southern Environmental Law Center
Mike Runge	United States Geological Service
Nick Sisson	National Marine Fisheries Service
Nick Zenkin	Lautec
Paul Phifer	Atlantic Shores Offshore Wind
Rachael Manhard	AKRF, Inc.
Sam Denes	JASCO Applied Sciences
Sarah Courbis	Advisian Worley Group
Sarah Grace Trabue	Columbia University
Sharon Kramer	H.T. Harvey & Associates
Stefan Bräger	BioConsult SH & GmbH & Co. KG
Susan Parks	Syracuse University
Taffy Williams	New York Whale and Dolphin Action League
Tim Ennis	Vineyard Wind
Todd Callaghan	Massachusetts Office of Coastal Zone Management
Verena Peschko	University of Kiel
Vicki Cornish	Marine Mammal Commission

Appendix B: Definitions and Information Included in Research Objectives

Based on several conceptual frameworks for anthropogenic impacts to marine mammals (Chief of Naval Operations, Energy & Environmental Readiness Division, 2013; Kraus et al. 2019; Sandia National Laboratories 2020; NSB Shell Baseline Studies Program 2021), the workgroup identified four overarching research areas for further discussion: Occurrence, conditions and stimuli, response, and consequences (see Background section). Within each of these four categories, workgroup members identified a range of possible research objectives (Table C1), and discussed specifics for each objective, including:

- Theme within each overarching research area
- Taxonomic group
- Geographic region
- Spatiotemporal scale and development phase of interest
- Possible methods
- Additional relevant information (i.e., other ongoing research to build from).

Themes Within Each Overarching Research Area

Occurrence	**Conditions and Stimuli**	**Response**	**Consequence**
• Presence • Distribution and Abundance • Behavior • Physiology • Diet • Health	• Exposure (Noise) • Exposure (Vessel Strike) • Habitat/Ecosystem: Biological • Habitat/Ecosystem: Physical	• Behavioral Response (Acute[1]) • Behavioral Response (Chronic) • Acoustic response (Masking, Lombard, TTS) • Physiological Response • Body Condition Response • Injury and Mortality	• Individual Effects • Population Effects • Multi-stressor Effects • Risk Assessment (Uncertainty)

[1] For behavioral responses, "acute" as used here indicates a timescale of hours to days (such as acute responses to piling activity), while "chronic" suggests months to years (for example, displacement/attraction to operational wind farms).

Taxonomic Categories

Large Whales (Baleen)	**Odontocetes**	**Pinnipeds**
• North Atlantic right whale • Fin • Sei • Minke • Humpback • Blue • Bryde's	• Sperm Whale • Killer Whale • Beaked whales • Harbor Porpoise • All other small and medium toothed cetacean species	• Harbor Seal • Grey Seal

Geographic regions

- Southern New England
- New York Bight (New York and northern New Jersey)
- Mid-Atlantic (Southern New Jersey to North Carolina)
- *Gulf of Maine (future)*

Spatiotemporal scale and development phase of interest

Defines necessary spatial scale for addressing the objective, e.g., whether focus is at OSW sites or elsewhere, and whether it should be examined at a single OSW development site, multiple sites, or at a regional scale including sites outside of OSW areas. Also defines duration of study and OSW development phase of interest, if applicable. Development phases include pre-construction, construction, operations, and decommissioning.

Potential methods

A variety of field and analytical methods are mentioned in brief in this report. A detailed examination of these approaches is outside the scope of this report. However, some additional information on several common approaches suggested for OSW-related monitoring is available in Integral Consulting Inc (2020) and citations therein. A summary of the more common approaches is included in Appendix D.

Additional information

There are significant ongoing research initiatives in the eastern U.S. for marine mammals; specific examples are listed where relevant for a given objective in the main text of this report. For further information, see the list of organizations involved in ongoing research efforts in Appendix G.

Appendix C. Prioritization Processes

From the full list of possible research objectives identified by the group (Table C1), workgroup members used a series of approaches to collectively prioritize objectives to address in the next five years, as depicted in Figure 1 in the main document. First, workgroup leads identified several topics as being outside the temporal focus of the workgroup assignment (e.g., research studies that could not be initiated within the next five years) and designated those research objectives as “Longer-term Priorities”. Subsequently, workgroup participants completed a prioritization survey to select and rank the highest priority objectives to address in the next five years from within each of the four overarching research areas (Table C2). Workgroup members were asked to consider three criteria when identifying priorities:

- *Urgency of the information need.* Objectives should be prioritized that will most effectively improve our understanding of cumulative impacts and inform decision making.
- *Sequencing of objectives.* If the results of a hypothetical Study #1 are needed to help shape the design of a subsequent Study #2, Study #1 should be designated as higher priority in the short term.
- *Ability to inform Consequence models* such as PCoD models

Given the regulatory importance of all marine mammals under the Marine Mammal Protection Act, workgroup members were asked to independently identify priorities for research for each of the three major taxonomic groups (baleen whales, odontocetes, and pinnipeds). However, workgroup members overwhelmingly indicated that baleen whales were the highest priority for research in relation to offshore wind energy development. A poll at the third workgroup meeting asking participants to choose the taxonomic group they considered to be the highest priority overall resulted in 96% of respondents selecting baleen whales, 4% selecting odontocetes, and 0% selecting pinnipeds (n=35).

Following selection of the high priority research objectives for each taxonomic group from within each overarching research area, the highest-ranked objectives for each taxon were pooled across research areas. A live poll was conducted at the third workgroup meeting to identify the objectives on which to focus further taxon-specific discussions (Table C3). For pinnipeds and odontocetes, the top three topics from the poll were selected for further discussion. Due to the overall priority of baleen whale research as identified via the poll (above), the top six baleen whale topics were selected for further discussion. These twelve topics represent the Priority Levels 1-2 short-term research objectives listed in the main body of this report (topics were consolidated across taxa in cases where the same objective was prioritized for multiple taxonomic groups).

Following identification of the seven cross-taxon high-priority research objectives, a final survey was issued to workgroup members to assess which of the seven topics were of greatest immediate need (using the same criteria defined above; Table C4). Workgroup members were asked to select their top three topics from the list of seven (n=53 responses). The three research objectives that received a vote from at least 45% of respondents were categorized as Priority Level 1 in this report, while the other four are designated as Priority Level 2.

Table C1. Research objectives identified by workgroup members as short-term priorities.

Research Areas	**Objective**
Occurrence	Better understand auditory capabilities of species of interest[17]
Occurrence	Determine spatially and temporally explicit species presence in OSW development areas
Occurrence	Establish baseline of physiological parameters such as stress hormones
Occurrence	Establish individual baseline movements and behavioral patterns (e.g., foraging, diving, reproduction) in OSW development areas
Occurrence	Estimate habitat use, distribution and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns
Occurrence	Examine diet composition and primary prey species, particularly in/near planned OSW areas
Occurrence	Examine energetic requirements and health condition of individuals, particularly reproductive females
Occurrence	Identify baseline vocalization behavior, including seasonality and acoustic characteristics, in OSW development areas
Conditions and Stimuli	Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas
Conditions and Stimuli	Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases
Conditions and Stimuli	Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods
Conditions and Stimuli	Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods
Conditions and Stimuli	Evaluate changes in traffic patterns related to OSW activities. Includes vessel traffic directly associated with OSW as well as potential changes in other traffic patterns in response to OSW development
Conditions and Stimuli	Evaluate vessel strike risk to which marine mammals could be exposed from OSW activities[18]
Response	Assess physiological/stress consequences of exposure to OSW stressors
Response	Evaluate relative threat of mortality or serious injury from noise associated with OSW and non-OSW activities
Response	Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities
Response	Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment
Response	Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term responses (specifically avoidance or attraction) to OSW development areas to support development and refinement of risk and consequence assessment
Response	To what degree do animals experience potential auditory effects of various types (Masking, Lombard Effect, Temporary Threshold Shift)
Consequences	Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative impacts on moderate and long timescales in OSW areas
Consequences	Assess individual energetic consequences of behavioral changes due to OSW development activities

[17] This objective was not further explored during workgroup discussions and thus is not listed in the body of this report.

[18] Following the initial prioritization survey and further group discussion, this objective was judged to be too similar to the response objective "Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities." The two topics were consolidated in the body of this report under the latter title.

Table C2. Results of the workgroup prioritization survey. Objectives were prioritized within each taxonomic group (baleen whales, odontocetes, and pinnipeds) and overarching research area (occurrence, conditions and stimuli, response, and consequences). Results are presented in weighted rank order for each taxon-category combination. Topics with higher scores were generally indicated by workgroup members to be higher priority (n=35).

Baleen Whales – Occurrence	
Score (0-8)	**Question**
7.12	Estimate habitat use, distribution and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns
6.76	Determine spatially and temporally explicit species presence in OSW development areas
5.85	Establish individual baseline movements and behavioral patterns (foraging, diving, reproductive etc.) in OSW development areas
4.24	Identify baseline vocalization behavior, including seasonality and acoustic characteristics, in OSW development areas
3.35	Examine diet composition and primary prey species, particularly in/near planned OSW areas
3.27	Examine energetic requirements and health condition of individuals, particularly reproductive females
2.97	Establish baseline of physiological parameters such as stress hormones
2.50	Better understand auditory capabilities of species of interest
Odontocetes – Occurrence	
Score (0-8)	**Question**
7.12	Estimate habitat use, distribution and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns
6.76	Determine spatially and temporally explicit species presence in OSW development areas
5.85	Establish individual baseline movements and behavioral patterns (foraging, diving, reproductive etc.) in OSW development areas
4.24	Identify baseline vocalization behavior, including seasonality and acoustic characteristics, in OSW development areas
3.35	Examine diet composition and primary prey species, particularly in/near planned OSW areas
3.27	Examine energetic requirements and health condition of individuals, particularly reproductive females
2.97	Establish baseline of physiological parameters such as stress hormones
2.50	Better understand auditory capabilities of species of interest
Pinnipeds – Occurrence	
Score (0-8)	**Question**
7.09	Determine spatially and temporally explicit species presence in OSW development areas
7.03	Estimate habitat use, distribution and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns
5.88	Establish individual baseline movements and behavioral patterns (foraging, diving, reproductive etc.) in OSW development areas
4.35	Identify baseline vocalization behavior, including seasonality and acoustic characteristics, in OSW development areas
3.26	Examine diet composition and primary prey species, particularly in/near planned OSW areas
3.03	Establish baseline of physiological parameters such as stress hormones
2.79	Examine energetic requirements and health condition of individuals, particularly reproductive females
2.56	Better understand auditory capabilities of species of interest

Baleen Whales – Conditions and Stimuli	
Score (0-6)	**Question**
4.50	Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas
4.35	Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases
3.88	Evaluate vessel strike risk to which marine mammals could be exposed from OSW activities
3.50	Evaluate changes in traffic patterns related to OSW activities. Includes vessel traffic directly associated with OSW as well as potential changes in other traffic patterns in response to OSW development
3.03	Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods
1.74	Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods
Odontocetes – Conditions and Stimuli	
Score (0-6)	**Question**
4.82	Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas
4.74	Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases
3.67	Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods
2.91	Evaluate changes in traffic patterns related to OSW activities. Includes vessel traffic directly associated with OSW as well as potential changes in other traffic patterns in response to OSW development
2.48	Evaluate vessel strike risk to which marine mammals could be exposed from OSW activities
2.24	Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods
Pinnipeds – Conditions and Stimuli	
Score (0-6)	**Question**
4.82	Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas
4.42	Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases
4.27	Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods
2.88	Evaluate changes in traffic patterns related to OSW activities. Includes vessel traffic directly associated with OSW as well as potential changes in other traffic patterns in response to OSW development
2.63	Evaluate changes in physical oceanographic features in OSW development areas from the pre-construction to operational periods
2.03	Evaluate vessel strike risk to which marine mammals could be exposed from OSW activities

Baleen Whales – Response	
Score (0-6)	**Question**
4.71	Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment
4.15	Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term responses (specifically avoidance or attraction) to OSW development areas to support development and refinement of risk and consequence assessment
3.94	Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities
3.00	Assess physiological/stress consequences of exposure to OSW stressors
2.88	To what degree do animals experience potential auditory effects of various types (Masking, Lombard Effect, Temporary Threshold Shift)
2.29	Evaluate relative threat of mortality/injury (PTS) from noise associated with OSW and non-OSW activities
Odontocetes – Response	
Score (0-6)	**Question**
4.91	Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment
4.45	Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term responses (specifically avoidance or attraction) to OSW development areas to support development and refinement of risk and consequence assessment
3.39	Assess physiological/stress consequences of exposure to OSW stressors
3.24	Evaluate relative threat of mortality/injury (PTS) from noise associated with OSW and non-OSW activities
3.13	To what degree do animals experience potential auditory effects of various types (Masking, Lombard Effect, Temporary Threshold Shift)
1.91	Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities
Pinnipeds – Response	
Score (0-6)	**Question**
4.88	Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment
4.85	Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term responses (specifically avoidance or attraction) to OSW development areas to support development and refinement of risk and consequence assessment
3.84	Assess physiological/stress consequences of exposure to OSW stressors
3.06	To what degree do animals experience potential auditory effects of various types (Masking, Lombard Effect, Temporary Threshold Shift)
2.75	Evaluate relative threat of mortality/injury (PTS) from noise associated with OSW and non-OSW activities
1.56	Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities

Baleen Whales – Consequences	
Score (0-2)	**Question**
1.58	Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative effects on moderate and long timescales in OSW areas
1.42	Assess individual energetic consequences of behavioral changes due to OSW development activities
Odontocetes – Consequences	
Score (0-2)	**Question**
1.58	Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative effects on moderate and long timescales in OSW areas
1.42	Assess individual energetic consequences of behavioral changes due to OSW development activities
Pinnipeds – Consequences	
Score (0-2)	**Question**
1.63	Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative effects on moderate and long timescales in OSW areas
1.38	Assess individual energetic consequences of behavioral changes due to OSW development activities

Table C3. Results of three live polls taken during the third workgroup meeting. For each taxonomic group, participants chose their three highest priority objectives for further discussion in breakout groups (table presents number of votes per objective for each taxonomic group). The top 3-6 objectives for each taxonomic group that were selected for further discussion are starred in the table and listed below. Forty-eight workgroup members voted in the poll, though not all participants used all three of their votes for each question.

Research Objective	**Baleen Whales**	**Odontocetes**	**Pinnipeds**
Assess individual energetic consequences of behavioral changes due to OSW development activities	5	5	0
Determine spatially and temporally explicit species presence in OSW development areas	17*	20*	14
Develop transparent, replicable, ecosystem-based risk assessment models for estimating cumulative effects on moderate and long timescales in OSW areas	9	12	16
Establish individual baseline movements and behavioral patterns (foraging, diving, reproductive etc.) in OSW development areas	24*	18	22*
Estimate habitat use, distribution and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns	42*	37*	33*
Evaluate acute noise conditions to which marine mammals could be exposed at OSW development areas	5	8	5
Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases	9*	9	2
Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods	0	0	17*
Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities	11*	0	0
Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment	16*	20*	11
Identify spatial-temporal-acoustic contextual conditions associated with potential longer-term avoidance or attraction to OSW development areas to support risk and consequence assessment	0	15	15

Table C4. Results of the final prioritization survey on short-term research objectives. Participants identified their top three short-term research objectives from the seven identified during polling at the last workgroup meeting (Table C3). Scores indicate the percentage and number of respondents who selected each objective (n=53).

Short-term Research Objectives	
Score	**Topic**
81% (43)	Estimate habitat use, distribution, and abundance in OSW development areas by season, and identify dynamic environmental variables driving these patterns (Baleen Whales, Odontocetes, Pinnipeds)
60% (32)	Identify acoustic exposure and contextual conditions associated with potential acute response to OSW stressors to support development and refinement of risk and consequence assessment (Baleen Whales, Odontocetes)
45% (24)	Establish individual baseline movements and behavioral patterns (foraging, diving, reproductive etc.) in OSW development areas (Baleen Whales, Pinnipeds)
38% (20)	Evaluate relative threat of mortality/injury from vessel strikes associated with OSW and non-OSW activities (Baleen Whales with particular focus on North Atlantic right whales)
32% (17)	Evaluate ambient sound levels (soundscapes) in OSW development areas prior to development activities, as well as during all development phases (Baleen Whales)
28% (15)	Determine spatially and temporally explicit species presence in OSW development areas (Baleen Whales, Odontocetes)
15% (8)	Evaluate changes in ecosystem and prey conditions in OSW development areas from the pre-construction to operational periods (Pinnipeds)

Appendix D. Common Technologies and Methods

Table 1. Summary of common technologies and methods (adapted from Integral Consulting Inc 2020).

Method	Description	Advantages	Disadvantages
Vessel-based and aerial-based line transect observational surveys	The essential methodology utilized by both vessel and aerial programs involves the transit of a prescribed transect through a sampling area while one or more human observers monitor prescribed portions of the sea surface recording a suite of data (e.g. species, number, behavior), for observed marine mammals. Both vessel-based and aerial surveys have been successfully utilized to infer distribution, estimate density or abundance, and investigate behavior. Aerial and vessel surveys have also been used extensively to mitigate and monitor the effects of anthropogenic activities such as petroleum and wind energy development.	• Established methods • Extensive history or use • Opportunities for collection of photography • Can include simultaneous co-located sampling of environmental data (vessel-based) • Relatively long observation opportunities (vessel-based) • Covers large areas relatively quickly (aerial-based)	• Presence of survey platform affect target species influencing data • Costly • Slow process when covering large areas (vessel-based) • High risk profile for pilots and observers (aerial-based)
Passive Acoustics (PAM)	PAM systems take advantage of the fact that marine mammals utilize acoustic sensory capabilities and generation of sound to meet critical life functions such as locating food, identifying potential predators and other threats, communicating with cohorts, and mating, and use these sounds to detect, classify and track cetaceans. PAM systems include a) fixed bottom-mounted recorders that may be either cabled to a shore base or operate autonomously, b) towed hydrophones or hydrophone arrays deployed behind survey vessels, c) acoustic tags deployed on marine mammals to record and measure sounds that they produce and that they receive from other biological and anthropomorphic sources, d) hydrophone sensor or towed arrays associated with autonomous underwater vehicles and unmanned surface vehicles, and e) anchored surface buoys with either surface or suspended sensors and arrays.	• Collect data over extended periods and diverse conditions • Operate autonomously • Also collect data on the acoustic environment and potential effects	• Data processing is time consuming and costly • Impacted by ambient noise (masking and behavior change) • Primarily presence / absence data with variable localization capacity
Tagging	Attachment of animal-borne devices (transmitters) that are capable of signal transmission. Modern transmitters are capable of collecting a variety of data related to the movement, behavior, and physiology of the tagged animal. These devices may store data on board to be retrieved upon recovery after release from the animal, or may transmit data opportunistically when the animal is at the surface through VHF radio, cellular, or satellite communication links. Tags allow researchers to track marine mammal movements both two dimensionally and three dimensionally within their marine environment, and can provide data such as swimming speed, depth and duration of dive, and vocalization that can provide dose-response interpretation of the effects of exposure to stimuli such as vessel noise, sonar, or seismic air guns.	• Useful for tracking animals that spend limited time at the sea surface, occur in remote areas, and are highly migratory • Provide insight into habitat requirements and feeding behavior • Can measure physiological parameters, received sound levels, and behavioral parameters	• Logistical, legal, and ethical challenges

Method	Description	Advantages	Disadvantages
Photogrammetry	The use of photography to identify individual animals within a population. The practice is based upon the presence of morphological traits that allow investigators to differentiate among individual of a species and population. Body parts that are typically useful for photogrammetric identification include possible presence and pattern of callosities often present on the head and rostrum, variation in the shape, notches, scars, coloration of the fluke, shape and presence of scars on the dorsal fin, presence of scars on observable parts of the body, and patterns of coloration. Matching of markings between photographs produce archival histories of time and place of occurrence of individuals, as well as matching with associated data such as behavioral mode and conspecific associates. Images from the North Atlantic Right Whale Catalog have been utilized to develop high confidence population estimates and trends, identify important habitat, and assess animal health.	• Can develop histories of individual animals • Non-invasive	• Time-intensive • Requires large numbers of observations for many types of analyses
Health Assessment	• Measurement of physical characteristics derived from photographs, including body measurement and skin condition, blowhole cyamids, and rake marks, to evaluate the health members of the right whale population. • Biological samples that can be acquired during vessel and small boat surveys to provide information on hormone levels to assess stress, reproductive indicators, and other health metrics. Derivation of health indicators and genetic information from minimally invasive sampling such as fecal and expired breath is a rapidly expanding practice and is incorporating the use of emerging technologies such as unmanned aerial systems (UAS). • Well established primarily for Northern Atlantic right whale in AOCS	• Support development of multiple population metrics • Individual and population health and impacts assessment	• Principally based on photography acquired from aerial and vessel surveys; fecal studies; biopsies and necropsies
Ecological Assessment and Modeling	Combines marine mammal sighting data with information about the physical and biological characteristics of the water column and the distributions of lower trophic level organisms, such as fishes and plankton, to place spatiotemporal distribution data into an ecosystem context. This can allow for probabilistic estimation of distributions and abundance in areas that have not been surveyed, based on correlations between marine mammal distributions and physical and biological conditions, as well as allowing for the discrimination between changes in cetacean populations related to natural environmental variability and changes due to anthropogenic effects.	• Based upon integration of survey data and marine sampling • Provide a tool for evaluating effects of environmental change	• Requires development and integration of large data sets

Appendix E. Consequence Models

A range of models already exist for estimating exposure, behavior, and consequence of stressors on marine mammal individuals and/or populations (Table E1). These models take a variety of approaches for evaluation at the individual animal or population level, with some able to do both. Animal-focused models and equation-based models (Figure E1) are tools that can be used to assess along the spectrum of individuals to populations.

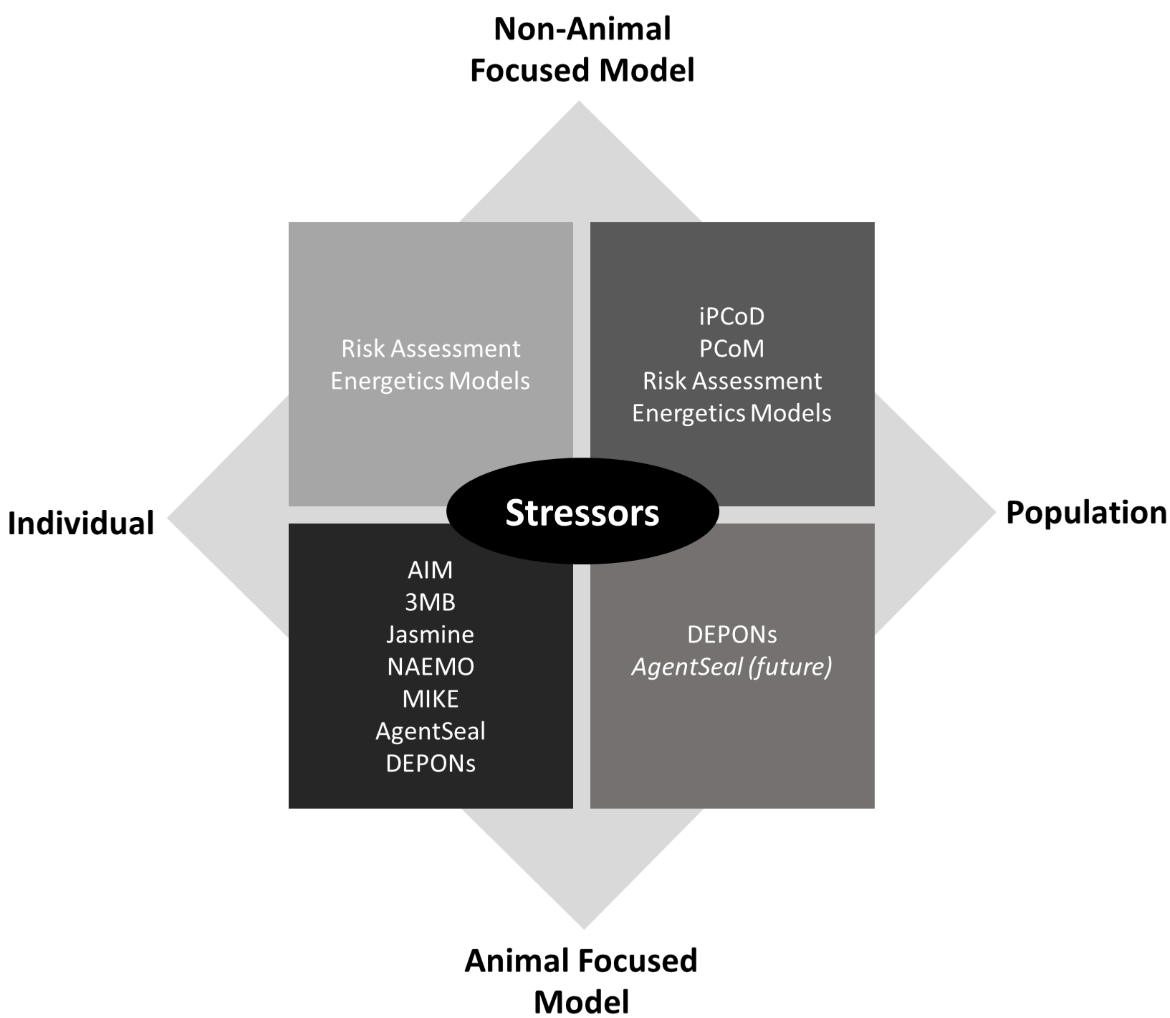

Figure E1. Summary of the types of models outlined in Table E1. While some existing marine mammal models are focused more on individuals, others are explicitly focused on populations, and while some are based on simulations of how animals move through and interact with their environment (animal-focused models), others are equation-based and instead focus on estimation of parameters within the model to inform effect assessments.

Table E1. Existing exposure, behavior, and consequences models for marine mammals.

Model	Developer	Purpose	Animal - Focuse d	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
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)	Strategic Environmental Research & Development Program/ Office of Naval Research	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

Additional details on specific models include:

- **AIM, 3MB, JASMINE,** and **NAEMO** were developed to address U.S.-specific needs for individual exposure estimates under the Marine Mammal Protection Act.
- **iPCoD** (interim Population Consequences of Disturbance model)[19] was developed in the UK by applying the PCAD (Population Consequences of Acoustic Disturbance) framework[20] and PCoD (Population Consequences of Disturbance model) to support the need to advance impact assessments beyond individual exposure estimates (Figure E2). Initiatives were originally funded by the U.S. Navy with additional support from the oil and gas sector, with the model funded by UK government and Crown Estate.
- Modules within **MIKE** have been developed to advance exposure modelling by integrating more parameters.
- **DEPONs** was developed specifically for harbour porpoise, and advances modelling to range from individual exposure to population consequences.
- **AgentSeal** was developed in the UK to address effects to seals and is currently able to assess individual exposures.
- **PCoMS** is in development to address multiple stressors.
- The **Risk Assessment Framework** (Southall et al. 2018, Figure E3), which utilizes expert elicitation, was developed as an interim approach by an Expert Working Group supported by BOEM and NMFS to guide current regulatory decisions[21,22].
- **Energetics models** are a general approach with myriad applications relevant to the effects of disturbance. "Energetics models" include any mechanistic model that considers how an individual animal acquires energy (i.e., energy intake) balanced against the costs of life-history functions (i.e., energy expenditure, including maintenance and survival, growth, and reproduction) in order to maximize its fitness. The effects of disturbance can be assessed at the individual or population level, depending on the model, and have applications for PCoD (where net energy loss is the pathway considered). Models can have different levels of complexity and required inputs.

[19] SMRU Consulting. Interim Population Consequences of Disturbance www.smruconsulting.com/products-tools/pcod/ipcod/

[20] Development of transfer functions for the Population Consequences of Acoustic Disturbance Model (PCAD) www.soundandmarinelife.org/innovation/development-of-transfer-functions-for-the-population-consequences-of-acoustic-disturbance-model-pcad.aspx

[21] BOEM Center for Marine Acoustics Accomplishments www.boem.gov/environment/center-marine-acoustics-accomplishments

[22] Taking and Importing Marine Mammals; Taking Marine Mammals Incidental to Geophysical Surveys Related to Oil and Gas Activities in the Gulf of Mexico. A Rule by the National Oceanic and Atmospheric Administration on 01/19/2021. https://www.federalregister.gov/documents/2021/01/19/2020-27252/taking-and-importing-marine-mammals-taking-marine-mammals-incidental-to-geophysical-surveys-related

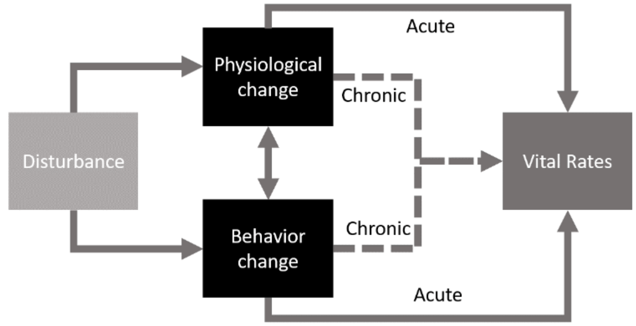

Figure E2. Summary of Population Consequences of Disturbance (PCoD) model structure (reproduced from SMRU Consulting).

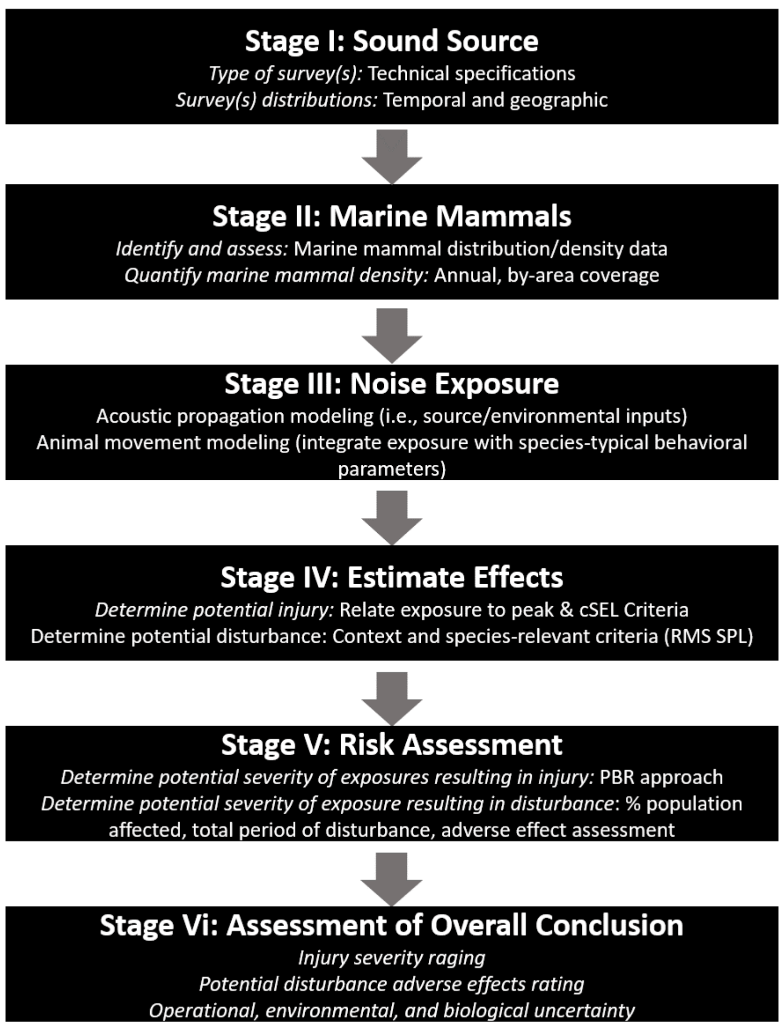

Figure E3. The overall framework organization and staged progression of the BOEM- and NMFS-funded Expert Working Group Risk Assessment Framework to assess the biological significance of noise exposure on marine mammals (Southall et al. 2018).

Appendix F. Recommendations for Data Transparency and Data Sharing

In addition to addressing the research objectives identified above, the workgroup recommended the following practices for data collection, standardization, sharing, and coordination:

- Data collection, data metrics and metadata characterization should follow, at minimum, published standards where applicable such as:
    - ISO 18405:2017 (Underwater acoustics — Measurement of radiated underwater sound from percussive pile driving)[23]
    - ISO 18406: 2017 (Underwater acoustics —Terminology)[24]
    - National Centers for Environmental Information Standards[25]
- Data should be made publicly available in a timely fashion.
- Data should be shared through expanded existing databases and data portals, including but not limited to:
    - Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS)[26] and Mid-Atlantic Regional Association of Coastal Ocean Observing Systems (MARACOOS)[27]
    - The Northeast and Mid-Atlantic Ocean Data Portals[28,29]
    - North Atlantic right whale Consortium/ New England Aquarium North Atlantic right whale Catalog[30]
    - Ocean Biodiversity Information System – Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP)[31]
- Developers and independent scientists should coordinate to facilitate integration of research efforts and allow compilation and aggregation of data across such efforts, as well as to avoid duplication.

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[23] ISO. Underwater acoustics – Measurement of radiated underwater sound from percussive pile driving http://www.iso.org/obp/ui/#iso:std:iso:18406:ed-1:v1:en
[24] ISO. Underwater acoustics – Terminology http://www.iso.org/standard/62406.html
[25] Metadata, National Centers for Environmental Information http://www.ncei.noaa.gov/resources/metadata
[26] NERACOOS http://www.neracoos.org/
[27] MARACOOS https://maracoos.org/
[28] Northeast Ocean Data Portal http://www.northeastoceandata.org/
[29] Mid-Atlantic Ocean Data Portal https://portal.midatlanticocean.org/
[30] North Atlantic Right Whale Consortium, North Atlantic Right Whale Catalog http://rwcatalog.neaq.org/#/
[31] OBIS-SEAMAP https://seamap.env.duke.edu/

Appendix G. Ongoing Research Initiatives

There are significant ongoing research initiatives in the eastern U.S. for marine mammals, and particularly for North Atlantic right whales, coordinated through the North Atlantic right whale Consortium annual meetings (https://www.narwc.org). Specific examples are listed in the main text of this report. These ongoing research efforts include:

- NEFSC and the Southeast Fisheries Science Center marine mammal research programs: aerial and shipboard surveys; acoustic surveys; multi-species
- New England Aquarium Right Whale Research Program: North Atlantic Right Whale Catalog; aerial and shipboard surveys; physiological studies; habitat modelling; ship strike risk
- Center for Coastal Studies: Cape Cod focus; aerial and shipboard surveys; feeding ecology; entanglement risks
- Cornell University: acoustic studies
- Woods Hole Oceanographic Institution: acoustics; thermal cameras; health assessment/body conditions/ physiology studies
- Syracuse University: Large whale acoustic ecology studies
- U.S. Navy regional research: multiple partners and projects
- Wildlife Conservation Society: New York Bight focus; acoustic studies; boat-based surveys; cetacean population studies (species identification, genetics, stable isotopes, eDNA)
- NYSERDA: aerial and shipboard research
- Massachusetts Clean Energy Center: aerial surveys; acoustics; prey studies
- Rutgers University: currently working on a baseline assessment of short- and long-term diet composition of large whales in the mid-Atlantic using stable isotope analysis and fatty acid analysis