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Monitoring of Marine Life During Offshore Wind Energy Development—Guidelines and Recommendations

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Introduction

The development of offshore wind energy will play a key role in the critical transition away from harmful fossil fuels to a clean energy economy. If done right, offshore wind power provides an opportunity to fight climate change, reduce local and regional air and water pollution, and grow a new industry that supports thousands of well-paying jobs. While the need for this transition is only becoming more urgent,[1] we can and must ensure that all offshore wind in the United States is developed responsibly and in a manner that minimizes impacts to biodiversity and the ecosystem.

Responsible development of offshore wind energy: (i) avoids, minimizes, mitigates, and monitors for adverse impacts on wildlife and habitats; (ii) minimizes negative impacts on other ocean uses; (iii) includes robust consultation with Native American tribes and communities; (iv) meaningfully engages state and local governments and stakeholders from the outset; (v) includes comprehensive efforts to avoid negative impacts to environmental justice communities; and (vi) uses the best available scientific and technological data to ensure science-based and stakeholder-informed decision making.

[1] *See*, *e.g.*, https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/.

The foundation of all longitudinal monitoring of habitat change begins with obtaining a robust baseline of data/information. Many of the habitats and species that may be affected by offshore wind development are already in a dynamic relationship with existing ocean uses and ocean processes and face additional shifts due to climate change independent of other stressors. While there is some existing knowledge regarding these interactions, offshore wind energy development will occur in ecosystems for which there is inadequate baseline data. This poses many unanswered questions in terms of how habitats and species will be affected and potentially impacted. Gathering existing data, continuing ongoing studies, and commencing other intersectional studies as soon as possible will provide a foundation upon which to build a rigorous monitoring regime.

This document represents a concise guide to the science-based principles and priorities for environmental monitoring that the environmental non-governmental organization (ENGO) community considers to be crucial to the advancement of responsible offshore wind development in the United States. Environmental monitoring is rooted in common scientific principles; however, every geography will have a unique set of priorities and considerations that are not necessarily transferable across regions. To bridge this gap, this document first provides guidance on the scientific principles that underpin ecosystem-based monitoring efforts, presents monitoring priorities common to all regions, and then presents considerations and monitoring recommendations specific to individual regions. Brief descriptions of monitoring methodologies are presented in the Appendix.[2]

1. Monitoring is a necessary aspect of responsible offshore wind energy development

A robust scientific research and monitoring plan to detect interactions between habitat, marine life, and offshore wind energy infrastructure and development activities, and any resulting impacts, as well as broader ecosystem-level effects, is a crucial component of responsible offshore wind energy development. Considering and adequately mitigating for these interactions will be necessary to ensure the success of this industry within the United States, including by meeting statutory requirements[3] and achieving the policy goals set forth by the administration.[4]

Offshore wind energy is a new industry in the United States and there are significant uncertainties regarding potential interactions and impacts with habitats and species that inhabit or use the waters or

[2] We acknowledge the establishment of the Regional Wildlife Science Entity (RWSE) in July 2021 will support design of research and monitoring for wildlife and offshore wind energy along the Atlantic coast. The recommendations set forth in this document are intended, in part, to inform the work of the subcommittees established under the RWSE to identify monitoring priorities. In March 2021, the Responsible Offshore Science Alliance (ROSA) also published an Offshore Wind Project Monitoring Framework and Guidelines for commercial and recreational fish species and their habitats. Here we supplement the ROSA monitoring framework and guidelines so agencies can consider a fully integrated monitoring program for both human and ecological considerations.

[3] Relevant laws include the National Environmental Policy Act (42 U.S.C. § 4321 et seq), the Endangered Species Act (16 U.S.C. ch. 35 § 1531 et seq), the Marine Mammal Protection Act (16 U.S.C. ch. 31 §§ 1361–1362, 1371-1389, 1401-1407, 1411-1418, 1421-1421h, 1423-1423h), and the Migratory Bird Treaty Act (16 U.S.C. §§ 703–712), among others.

[4] *See*, *e.g.*, https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.

airspace of the marine environment (Bailey et al. 2014). Species of concern include species of marine mammals, sea turtles, birds, bats, finfish, elasmobranchs, and invertebrates, that dwell in or utilize the benthic, pelagic, and above-water habitats where the equipment, infrastructure, and associated development and operations activities are located. It is paramount that offshore wind energy development is paired with monitoring and data collection, and that the information collected is used to adaptively manage offshore wind development. The most effective actions and measures to avoid, minimize, and mitigate impacts depend on timely and reliable information and its incorporation into iterative planning, permitting, and procurement decisions.

Monitoring is the foundation of this adaptive management approach (Lyons et al. 2008; *see also* West et al. 2019), and it is incumbent upon federal agencies to pre-identify points in time, or project milestones, when new information learned from monitoring results will be incorporated into procurement, regulation, permit conditions, new lease stipulations, guidance, accepted standards for best available technology, and industry-led best management practices. Monitoring results should also inform future monitoring methods and priorities.

Monitoring plays a crucial role at each stage of offshore wind energy development:

1. ***Planning and siting***. Good quality, long-term data are required to establish pre-development baseline ecological conditions and existing ocean uses for regions or sites where offshore wind energy may be developed (Likens and Lindenmayer 2018). Improved understanding of oceanographic and ecological processes will support predictions forecasting how habitats and distributions of marine life may change, and be potentially affected by, offshore wind development. Potential shifts in local marine usage resulting from offshore wind development, such as vessel traffic, and secondary effects on ecosystem, can also be assessed. Establishing a robust regional-scale ecological pre-development baseline should inform the earliest planning stages of offshore wind development (e.g., to avoid proposing wind energy areas within vulnerable habitats). More detailed multi-year area-specific pre-development baseline data are also required to inform responsible siting of offshore wind energy infrastructure within resulting wind energy areas (e.g., siting of lease areas, micro-siting of turbine foundations within lease areas). Multi-year data sets are also important to maximize statistical power and to capture dynamic processes in the ocean, and are needed to determine if observed changes are a result of impacts from offshore wind energy development or a result of rapid oceanographic changes brought about by climate change (e.g., Santora et al. 2017; Pershing et al. 2021). In addition, pre-development baseline data can inform monitoring priorities for the lifetime of offshore wind energy projects (see (3), below) by identifying markers of ecological change (e.g., presence and/or behavior of specific species sensitive to environmental change, such as apex predators and temperature sensitive invertebrates) that can serve as indicators for ecosystem-level changes and impacts (Ureta et al. 2020).

2. ***During development activities***. Site assessment of lease areas and cable routes and construction and installation of offshore wind infrastructure will impact habitats and wildlife. Understanding the nature of these interactions, including potential cumulative interactions from multiple offshore wind development projects, is essential to informing impact assessments and permitting of offshore wind energy, the effectiveness of mitigation measures, and how to adaptively manage impacts when they do occur (Zwart et al. 2015). Real-time and near real-time monitoring studies appropriately designed to detect effects and potential impacts to a broad range of taxa and/or habitats, while maximizing efficiency of data collection across taxa and habitats, are required during development activities and should be informed by pre-development baseline monitoring efforts (see (1), above). Due to the temporary elevation in habitat stressors from siting and construction activities, the intensity and breadth of monitoring should be similarly heightened through these stages (e.g., Kraus et al. 2019).

3. ***Lifetime of offshore wind energy projects and development areas***. Offshore wind energy projects will be operational for approximately 30 years and may be subsequently renewed, meaning that offshore wind development areas (e.g., wind energy areas) may host operational wind energy projects for the foreseeable future. The effects and impacts of offshore wind energy development on habitats and species may change during the lifetime of the project or development area (e.g., Lindeboom et al. 2015). A long-term monitoring program based on key indicators of ecological change is needed to determine the long-term effects and impacts of offshore wind development on the marine environment, and to distinguish these changes from those caused by natural variation, climate change or other threats (Likens and Lindemayer 2018; see also Haase et al. 2018). The design of the long-term monitoring program should be informed by pre-development baseline monitoring efforts so that changes from the ecological pre-development baseline can be detected (Likens and Lindemayer 2018) and appropriate ecological indicators are selected (Ureta et al. 2020).

4. ***Technology selection.*** Near real-time and longer-term monitoring data could illuminate distinctions between different technologies (e.g., turbine blade height, foundation types, platform design, anchoring technology, nacelle/engine type, and bird and bat deterrent devices) that allow for or increase the likelihood of avoiding impacts in the first instance. These data should inform future permit conditions and mitigation decisions while feeding into a broader adaptive management strategy for existing projects. Moreover, integrating monitoring systems into infrastructures and activities at an early stage can reduce related cost and harmonize observing capability and capacity.

2. Scientific principles of ecosystem-based monitoring

Site assessment and characterization, construction, and operation of offshore wind energy will affect multiple taxa and habitats, both in-water and above-water, and may result in ecosystem-level changes when built out to industrial scale. Maintaining biodiversity can also be a critical factor for ecosystem functioning and resiliency to disturbance. It is therefore essential that a monitoring plan for offshore wind energy is designed in a way that can detect changes within the ecosystem at multiple spatial and temporal scales.

> **Ecosystem-based monitoring (EBM)** can be used to monitor the biodiversity and functioning of an ecosystem, including changes that may occur as a result of offshore wind energy development (e.g., Ruckelshaus et al. 2008; Pezy et al. 2020). An EBM plan represents a combination of efforts to monitor specific taxa as well as the broader environment and is organized as a nested hierarchy, comprising habitat zones encompassing communities of species at the broadest level down to specific individuals within a population at the most focused level. Ecosystem-based principles, such as those used in a monitoring plan, are inherently system focused--as the name implies. They represent a holistic view of a given ecosystem, and provide a framework that can be used to assess the health of an environment across all levels. This hierarchical framework provides a guide to determining the types of monitoring required to observe the ecological conditions in a specific region. The goal of an EBM plan being to build a monitoring framework that effectively aids and informs decision making with an allowable degree of uncertainty.

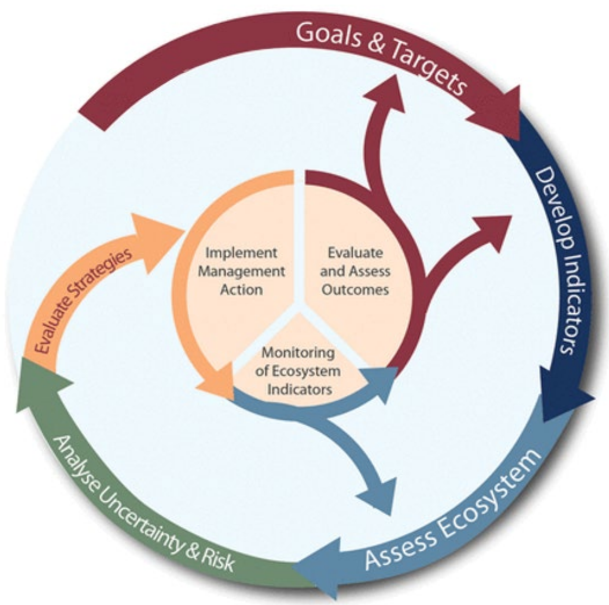

Figure 1. The cyclical, integrative nature of ecosystem-based monitoring and adaptive management. Adapted from the description of the NOAA Integrated Ecosystem Assessment process in Samhouri et al. (2014).

It is not possible to monitor all components of an ecosystem--either from a practical or resource availability perspective. It is necessary to identify a subset of monitoring priorities to focus efforts on. Selected priorities should comprise indicators that represent key components in an ecosystem and allow change to be identified and measured. They provide the basis to assess the status and trends in the condition of the ecosystem or of an element within the ecosystem (Samhouri et al. 2014; Ureta et al. 2020). The breadth of these recommendations is, in itself, an attempt to encapsulate the "unknowns" of potential or forecasted environmental impacts from offshore wind energy development.

As the ultimate goal is to assess the effects of offshore wind energy development on wildlife, habitats, and the broader ecosystem, indicators that are expected to be affected by offshore wind energy development should be selected. Examples of indicators can include ambient noise levels, biological soundscape characteristics (Elise et al. 2019), seabed recovery rate, or taxa or habitats of conservation concern (e.g., Red Knot, North Atlantic right whales, glacial moraines) (Samhouri et al. 2014; Sparrow et al. 2020). Taking advantage of "ships of opportunity" (e.g., existing research projects, fisheries surveys, etc.) can further increase efficiencies in monitoring effort.

Once collected, ecosystem indicator data has multiple uses. It can be assessed collectively to evaluate ecosystem status and trends relative to ecosystem management goals and targets, and also offers information on an individual basis, such as highlighting underlying causes in any changes in status or trends observed (Samhouri et al. 2014). Models can then be used to evaluate the influence of human activities (e.g., offshore wind energy development) and natural causes (e.g., oceanographic changes caused by climate changes) on the indicators. It is important that the degree of uncertainty in each indicator's response to changes in drivers and pressures be incorporated in a model's development (Samhouri et al. 2014). The outcomes of the empirical analysis and ecosystem modelling can then be used to evaluate the effectiveness of management strategies and inform adaptive management (Samhouri et al. 2014).

3. All monitoring data should be collected and made publicly available in a transparent manner

Major informatics challenges lie ahead with respect to using conventional and novel data types to enable: (i) attributing changes in managed species and ecosystems in wind energy areas to industry activity and/or other phenomena such as regional climate variability and change and; (ii) integrating data from various sources, locations, habitats and methods to produce robust assessments of change in key indicators that are useful for industry management.

As such, data collection should be centered around standard metadata conventions used by the Marine Cadastre, the Integrated Ocean Observing System (IOOS) and their Regional Associations, regional ocean data portals, or other long term collaborative data-management efforts. Raw data and synthesized data products should be regionally standardized and distributed through public data systems to increase transparency in offshore wind energy development. This should be carried out as part of a broader strategy to use the information collected to inform ongoing management decisions (Trice et al. 2021).

Increasing data accessibility also offers an opportunity to centralize existing data sources. Troves of data informative for monitoring the potential effects of offshore wind energy are stored across multiple repositories.[5] These data do not need to be centralized or duplicated, but could be more efficiently cataloged in a way that enables easy transmission between portals and allows the monitoring data to be readily accessed for inclusion in models and studies. This will require some standardization, and likely some translation of existing data into a coherent data cataloging format. Data stream planning by the IOOS Regional Associations is already advancing the ways in which many different conventional and emerging methodologies are feeding into Federally mandated assessments for fisheries and National Marine Sanctuary management (Ruhl et al. 2021). While these efforts to advance effective data streams are more pronounced for oceanographic data, additional processing is required to reach the same level with biological data streams and the work is still needed. Creating useful and publicly accessible informatics can entail a process of: (i) engagement to identify information and data integration and use needs, priorities, and concerns of stakeholders; (ii) integrating new and existing in situ, satellite and model observations for key managed spaces and reference areas; and (iii) creating curated data views and integrated assessment informatics (e.g., Iwamoto et al 2019).

4. Monitoring priorities common to all geographic regions

Marine ecosystems are not uniform across regions and vary in their resilience to environmental stressors. Knowledge gaps also differ across regions. While some monitoring priorities are relevant for almost all regions where offshore wind energy is being developed or is planned for development in the United States, each of the planning regions has its own set of unique considerations that need to be accounted for when designing a robust and effective monitoring plan.

This chapter first presents monitoring priorities common to all geographic regions and then sets forth considerations and monitoring priorities for each geographic region where offshore wind energy is advancing. Due to offshore wind energy advancing at different stages and rates in different regions,[6] priorities are being developed through a similarly phased process. As a result, this is intended to be a living document. Monitoring priorities for additional regions will be incorporated as they are finalized, and chapters will be periodically updated to reflect the latest scientific and technological advancements.

We recognize that BOEM, in partnership with other government agencies and non-governmental groups, has an existing body of research and monitoring projects underway on offshore wind development, including ones focused on specific regions of the OCS/ocean. These recommendations are intended to supplement and strengthen those studies by highlighting priority gaps in information important for the offshore wind planning process.

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[5] Including, but not limited to, climate and weather data collected by NOAA, biological data collected under the NMFS, geological and geophysical data hosted by BOEM, as well as the various data collected by academic institutes such as Cornell, WHOI, UPenn, University of South Florida on the East Coast, and Scripps, MBARI, Humboldt, UC Davis and CalPoly SLO on the west coast. Some of these data are already co-hosted by governmental agencies such as BOEM's Marine Cadastre (https://marinecadastre.gov) and NMFS CetSound, CetMap, (https://cetsound.noaa.gov/cda-index), and Duke University OBIS-SEAMAP (https://seamap.env.duke.edu/).

[6] *See*, *e.g.*, https://www.boem.gov/renewable-energy/state-activities.

Table 1. Monitoring priorities for all geographic regions (ordered by habitat and taxa; all equal priority). Exceptions for the Great Lakes region are noted by ""). Recommendations for specific priority taxa for each geographic region are described in the subsequent regional chapters.*

Priority Topic	**Scale**[7]	**Time Period**[8]	**Rationale**	**Tools/Techniques**
Altered hydrodynamics[9]	Local, Sub-regional, Regional	Pre- and Post-construction/ Operation	Individual turbines alter local hydrodynamics (turbulence, eddies) and underwater mooring lines and cable arrays associated with floating wind infrastructure may also have these effects. Cumulatively this may result in broader scale changes (e.g., altered stratification) that may affect settlement, recruitment, and connectivity, including for key prey species. Pairing monitoring of hydrodynamics with ecological monitoring could help elucidate the influence of altered hydrodynamics (if any) on the broader ecosystem (e.g. primary and secondary productivity—see recommendations below).	Acoustic Doppler Current Profiler (ADCP) measurements of current speed and direction Temperature measurements at different depths Hydrodynamic model predictions
Altered aerodynamics	Local, Sub-regional,	Pre- and Post-construction/ Operation	Depending on density, size of turbines, and size of the installation, local wind patterns may be altered in ways that might affect bird and bat behavior. Pairing monitoring of aerodynamics with ecological monitoring could help elucidate the influence of altered	In situ measurements of aerodynamics Aerodynamic model predictions

[7] Scales are defined as follows: Local scale = a single wind energy project area [and cable route?]; sub-regional = a geographic subset of the overall defined region that may include multiple adjacent or neighboring wind energy project areas; regional = an area that encompasses ecosystem-level processes occurring in the region and, in some cases, adjacent regions.
[8] Time periods are defined as follows: Pre-construction = all activities before turbine installation begins, including call area and wind energy area identification, and site assesement and characterization activities associated with individual leases; During construction = the foundation and turbine [and cable?] installation period; Post-construction = the time point immediately after the end of construction of foundations and turbines when the habitat is irreversably changed; Operation = the operations phase through to decommissioning. Specific monitoring priorities for the decommissioning phase may be developed, as necessary.
[9] For more information, *see* Carpenter et al. (2021).

Priority Topic	**Scale**[7]	**Time Period**[8]	**Rationale**	**Tools/Techniques**
			aerodynamics (if any) on airborne species.	
Underwater noise levels	Local, Sub-regional	Pre-, During, and Post-construction/ Operation	Underwater noise generated during offshore wind construction and operations (including vessel noise) has the potential to disrupt or displace noise sensitive species, including diving birds, fish, and marine mammals. Establishing baseline noise conditions is necessary to measure changes in noise levels. Monitoring can also inform whether different foundation types (e.g., floating technology, monopiles, gravity-based) emit different noise levels during operations.	Long-term passive acoustic monitoring of soundscapes Targeted noise monitoring during construction (e.g., pile driving) and operations Cumulative noise modeling
Biological sound characteristics	Local (multiple stations), Sub-regional	Pre-, During, and Post-construction/ Operation	Long-term soundscape characterization can provide data on density and distribution of taxa prior to, during, and post construction. This method can also provide information on recruitment levels of fish (i.e., the number of fish born that survive to the juvenile stage) during the operations phase.	Hydrophone arrays, acoustic transect equipment – like Slocum and wave gliders, surface-tethered arrays, etc.[10]
Electromagnetic field (EMF) effects on species locational cues[11]	Local, Sub-regional	Pre- and Post-construction/ Operation	EMFs emitted by offshore wind farm components may affect the ability of species (incl. invertebrates, fish, sea turtles) to derive locational cues, potentially effecting homing or migration, or predator-prey relationships. Data from in-situ monitoring should be paired with lab-based studies on	Free-ranging telemetry for single or multiple species (Before-After-Control-Impact (BACI) design) Direct measurement of

[10] Acoustic vector sensors may offer an effective and more affordable alternative to traditional arrays.
[11] For more information, *see* Degraer et al. (2021).

Priority Topic	Scale[7]	Time Period[8]	Rationale	Tools/Techniques
			species behaviors to different EMF exposure levels.	EMF emitted from in-water floating wind inter-array cables[12]
Benthic habitat utilization by invertebrates, commercially important species including juvenile stages, and non-commercially important species including juvenile stages	Local, Sub-regional	Pre-, During, and Post-construction/ Operation	Benthic habitats are complex habitat that supports the broader ecosystem. Benthic dwelling crustaceans, corals, mollusks, and worms are the foundation of the marine trophic structure. Understanding the effects of adding many novel structures (e.g., foundations, floating wind mooring lines and inter-array cables, towers, scour protection and cable mattresses), as well as from potential scour from floating wind anchors and catenary mooring systems, and possible mobilization of sequestered pollutants, is important for assessing impacts to species and communities (and particularly those where availability of complex hard structures are a limiting factor). Results could inform potential modifications to subsequent project designs that could enhance desired conditions, and inform regulators of potential impacts of various decommissioning requirement scenarios.	Benthic transects and sampling, water column net sampling. Data collection should include: species and condition counts, and size and taxon-specific biomass, and sediment sampling. Visual surveys using ROV/AUV Benthic characteristics mapping to correlate species and habitat health. Larval/adult traps Tagging of adults eDNA to determine the presence or absence of species

[12] We note that for EMF, additional research approaches are an important complement to field mesurements, including, but not limited to, mesocosm approaches to define behavioral responses and laboratory studies combined with cumulative effects modeling.

Priority Topic	**Scale[7]**	**Time Period[8]**	**Rationale**	**Tools/Techniques**
Distribution and habitat preferences of forage fish (e.g., sand lance) and invertebrates, including both commercially important and non-commercially important species and relative juvenile stages	Local, Sub-regional, regional	Pre-, During, and Post-construction/ Operation	Forage species represent a key component of marine food webs much like pelagic zooplankton and a wide range of vertebrate species, some of which also represent a commercial importance in addition to an ecological one. They require long term monitoring of species behavior and the broader use of complex habitats to minimize impacts from offshore wind development. Monitoring of these should encompass the effect of offshore wind development on species distribution and habitat use, since they may have implications for predator species and the broader ecosystem.	Side-scan sonar for some species. Tagging of adults. Acoustic backscatter Field examination of fish condition and gravidity eDNA techniques to determine the presence or absence of species are forthcoming (see, e.g., Chavez et al. 2021)
Migratory fish species monitoring (e.g., sturgeon, tuna, sharks, eels, cod).	Sub-regional, Regional	Pre-, During, and Post-construction/ Operation	Monitoring is needed to understand current migration routes and changes to migratory species behavior once wind arrays have altered pelagic habitat and are generating EMF that was previously not present. Migration patterns may also be affected by changes in currents and upwelling conditions changed by local and regional wind energy extraction.	Side-scan sonar Telemetry Commercial fishery catch data Current pattern and upwelling energy hydrodynamic monitoring. Acoustic tagging
*Marine mammal movements, distribution, and habitat use patterns	Local, Sub-regional, Regional	Pre-, During, and Post-construction/ Operation	Monitoring of marine mammal occurrence, distribution, and habitat use is needed for all regions, particularly as these species are experiencing dramatic distributional shifts because of	Manned aerial surveys (large whales)

Priority Topic	**Scale**[7]	**Time Period**[8]	**Rationale**	**Tools/Techniques**
			climate-driven shifts in prey distribution. Long-term pre- and post-construction monitoring is required to understand potential displacement effects, and whether any observed changes are a result of climate change, offshore wind development, or other factors. This information would also improve impact assessments and help advise monitoring and mitigation strategies.	Digital aerial surveys (small cetaceans) Shore-based surveys (coastal species and pinnipeds) Passive acoustic monitoring Animal-borne satellite, acoustic, and other sensory tags Prey sampling
*Sea turtle movements, distribution, and habitat use patterns	Local, Sub-regional, Regional	Pre-, During, and Post-construction/ Operation	A more complete picture of sea turtle occurrence and habitat use is needed for all regions. Long-term pre- and post-construction monitoring is required to understand potential displacement effects, and whether any observed changes are a result of climate change, offshore wind development, or other factors. Additional information on movement, dive patterns, and surface time would also improve impact assessments and help advise monitoring and mitigation strategies.	Acoustic telemetry of wild caught and rehabilitated sea turtles[13] Satellite telemetry Aerial surveys (visual, digital)

[13] Installation of acoustic receivers in WEAs would also benefit data collection for fish.

Priority Topic	Scale[7]	Time Period[8]	Rationale	Tools/Techniques
Bird and bat collision risk monitoring[14]	Local	Pre-construction and Post-construction/ Operation (until viable strike detection technology is installed)	Understanding which species are most at risk of collision is critical to estimating the impact of offshore wind energy projects on birds and bats. No existing monitoring technology is currently in a state to attribute collision events to species in the offshore environment, so technological advancement is crucial, and a combination of technologies will be required to better extrapolate predicted collision rates in the interim.	Floating met towers[15] with visibility sensors to collect data on weather conditions (i.e. fog) to better determine collision risk Marine radar to assess flight altitude and flux, especially during migration Tracking technologies to estimate macro-avoidance rates Near infrared video technologies and targeted behavioral studies to estimate micro-avoidance rates to inform Collision Risk Models
Bird and bat collision detection monitoring[16]	Local	Post-construction/ Operation	Collision, or strike, detection technology capable of identifying impact to species level will be critical for measuring impacts in	Near infrared video technologies combined with

[14] For more information, *see* "Addressing Avian Interactions with Offshore Wind. Considerations for Monitoring and Adaptive Management at Vineyard Wind I," developed by National Audubon Society, Connecticut Audubon, Audubon Society of Rhode Island, National Wildlife Federation, Defenders of Wildlife, Mass Audubon, New Jersey Audubon, and Audubon New York. https://drive.google.com/file/d/1nAR8-hypFySmCYEwKz_NkmaNVJFjN47K/view?usp=sharing at pp. 4-15.
[15] Floating met towers could also serve as a platform for vertical marine radar.
[16] For more information, *see* "Addressing Avian Interactions with Offshore Wind. Considerations for Monitoring and Adaptive Management at Vineyard Wind I," developed by National Audubon Society, Connecticut Audubon, Audubon Society of Rhode

Priority Topic	Scale[7]	Time Period[8]	Rationale	Tools/Techniques
			the offshore environment. No existing monitoring technology is currently in a state to attribute collision events to species in the offshore, so technological advancement is crucial, and a combination of technologies will be required to better extrapolate collision rates in the interim.	acoustic surveys may allow collisions to be detected (thermal video) and attributed to species (acoustic identification) Strike detection technologies should be deployed once available to monitor collisions for the lifetime of the project[17]
Bird displacement, attraction, and barrier effects[18]	Sub-regional, Regional	Pre- and Post-construction/ Operation	Baseline data is needed to understand how offshore wind development impacts 1) bird distribution in and around wind arrays and 2) migratory bird movements and pathways. These impacts may negatively impact energy budgets or result in habitat loss, resulting in changes in population vital rates-level effects, particularly for local breeding colonies. Offshore wind may create potential attraction or barrier affects to offshore wind turbines that might be different for floating platforms relative to fixed platforms. Floating turbines	Avian tracking studies, including automated radio telemetry nanotags and receivers, GPS satellite tags, geolocators and altimeters, as appropriate for the species of concern[19] Radar surveys to detect attraction to turbines

Island, National Wildlife Federation, Defenders of Wildlife, Mass Audubon, New Jersey Audubon, and Audubon New York. https://drive.google.com/file/d/1nAR8-hypFySmCYEwKz_NkmaNVJFjN47K/view?usp=sharing at pp. 4-15.

[17] Integration of strike detection technologies into the turbine infrastructure may be required.

[18] For more information, *see* "Addressing Avian Interactions with Offshore Wind. Considerations for Monitoring and Adaptive Management at Vineyard Wind I," developed by National Audubon Society, Connecticut Audubon, Audubon Society of Rhode Island, National Wildlife Federation, Defenders of Wildlife, Mass Audubon, New Jersey Audubon, and Audubon New York. https://drive.google.com/file/d/1nAR8-hypFySmCYEwKz_NkmaNVJFjN47K/view?usp=sharing at pp. 4-15.

[19] Requires installation of automated radio telemetry receivers throughout the turbine array. Floating Motus towers would also be helpful to establish baseline conditions.

Priority Topic	Scale[7]	Time Period[8]	Rationale	Tools/Techniques
			can also be further offshore and provide additional resting sites for migratory birds, which might increase collision risk in some species. Infrasonic impacts of blade/mast and tip vortices interaction with bird species	MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial and vessel surveys as appropriate Marine radar Infrasonic soundscape characterization.
Monitoring of trans-oceanic landbird migrants[20]	Local, Sub-regional, Regional	Pre- and Post-construction/ Operation	More information is needed on the migration patterns of nocturnal migrants (e.g., timing, flight heights, direction) to understand species-specific exposure to potential impacts from offshore wind energy development.	Automated radio telemetry nanotags (occurrence, flight height, direction) Marine radar (magnitude (i.e., flux), timing, altitude) Acoustic monitoring of flight calls (for birds with sufficient vocalizations)
Activity rate of bats in the	Local	Post-construction/ Operation	Given the apparent attraction of bats to turbines in the terrestrial environment, monitoring during the operational phase should be	Acoustic detectors (positioned to record activity

[20] For more information, *see* "Addressing Avian Interactions with Offshore Wind. Considerations for Monitoring and Adaptive Management at Vineyard Wind I," developed by National Audubon Society, Connecticut Audubon, Audubon Society of Rhode Island, National Wildlife Federation, Defenders of Wildlife, Mass Audubon, New Jersey Audubon, and Audubon New York. https://drive.google.com/file/d/1nAR8-hypFySmCYEwKz_NkmaNVJFjN47K/view?usp=sharing at pp. 4-15.

Priority Topic	Scale[7]	Time Period[8]	Rationale	Tools/Techniques
offshore wind project area[21]			the priority to understand whether and how bats are attracted to offshore wind turbines.	within the rotor swept zone)[22]

I. Atlantic

a. Southern New England (Connecticut, Rhode Island and Massachusetts)

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The waters off southern New England encompass highly productive waters and complex bottom habitats that support a high level of marine biodiversity, from fish to top predators. Glacial moraines are a complex bottom habitat that, in the contiguous United States, are mainly limited in distribution to the outer continental shelf near New England (Inspire Environmental 2020), with Cox Ledge being the dominant oceanographic feature in the region. Glacial moraines create a unique bottom topography that enables a high level of biodiversity and provides essential fish habitat (EFH) for numerous species, including several overfished populations, such as Atlantic cod, Atlantic wolffish, winter flounder, yellowtail flounder, and ocean pout (NMFS-NEFSCa,b). Four fish species listed as endangered under the Endangered Species Act (ESA) are also present in the region: giant manta ray, Atlantic salmon, Atlantic sturgeon, and shortnose sturgeon.[23] Among those, Atlantic sturgeon are reliant on hard bottom substrates such as glacial moraines as a feature in their habitat.[24] In contrast to sand and mud bottom types, complex habitats like glacial moraines have been shown to take longer to recover from disturbance (Khan & Smith 2020).

Loggerhead, leatherback, and Kemp's ridley sea turtles regularly occur in the region, primarily during the summer and fall (Kraus et al. 2016). Green turtles have not been recently sighted but are known to use shallow developmental habitats around eastern Long Island and Cape Cod (Kenney & Vigness-Raposa 2010). Loggerhead sea turtles and the North Atlantic population of green turtles are listed as threatened under the ESA and leatherback and Kemp's ridley sea turtles are endangered throughout their range.

[21] For more information, *see* Hein, C., Williams, K.A., and Jenkins, E. 2021. *Bat Workgroup Report for the State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts*. Report to the New York State Energy Research and Development Authority (NYSERDA). Albany, NY. 21 pp. https://www.nyetwg.com/2020-workgroups.

[22] The number of sampling stations will depend on the size and layout of the wind energy facility but should capture any variability in the site (e.g., nearest and farthest distance from shore).

[23] NMFS, ESA Threatened and Endangered Species Directory. https://www.fisheries.noaa.gov/species-directory/threatened-endangered.

[24] NMFS, Atlantic sturgeon. https://www.fisheries.noaa.gov/species/atlantic-sturgeon.

Twenty-six marine mammal species occur in the waters of this region, and particularly the area between the coasts of Rhode Island, Connecticut, and New York eastwards to Nantucket Shoals, is becoming an increasingly important foraging area for migratory large whale species, including the critically endangered North Atlantic right whale (Quintana-Rizzo et al. 2021), which is currently experiencing an Unusual Mortality Event.[25] Oceanographic studies conducted in the region confirm the presence of a zooplankton community composition, which is similar to that of Cape Cod Bay, a known hotspot for right whale feeding (O'Brien et al. 2021). Right whales have been observed feeding in the waters off Southern New England in all seasons and years since 2011, and observed social behaviors suggest that this area may also be used for courtship and mating (O'Brien et al. 2021). In addition, a Biologically Important Area for feeding has been designated for endangered fin whales east of Montauk point from March to October (LaBrecque et al. 2017), and feeding and social behaviors have also been regularly observed for humpback whales (Kraus et al. 2016; Leiter et al. 2017). Humpback whales and minke whales, which also occur in the area, are also currently experiencing an Unusual Mortality Event.[26] Harbor porpoise also frequent the region and have been identified as being extremely sensitive to noise (e.g., Tougaard et al 2009; Brandt et al. 2011; Dähne et al. 2013).

Three ESA-listed bird species: the Red Knot, Piping Plover, and Roseate Tern, as well as many other bird species of conservation concern (listed under the U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern (USFWS 2021), International Union for Conservation of Nature (IUCN) Red-List, or United Nations Convention on the Conservation of Migratory Species of Wild Animals (CMS)), including nocturnal migrants (Sorte & Fink 2017), regularly occur in the region. Numerous trans-Atlantic migrating land and shorebirds, many of which are protected under various state regulations, in addition to the Migratory Bird Treaty Act, have documented routes through the region (Sorte and Fink 2017). Many species use Monomoy National Wildlife Refuge, Nantucket, Muskegat, Block Island, and Long Island, among other islands along the southern New England coast, during migration. Nocturnally migrating passerines from across North America convene along Long Island, New England's southern coast and Cape Cod prior to beginning their southward trans-Atlantic migration in the fall (Clipp et al. 2020). Beach nesting birds, like Piping Plover, American Oystercatcher, Black Skimmer, Least Tern, Common Tern, and Roseate Tern, breed along these shorelines in the spring, forage offshore in the spring and summer, and travel over water for fall and spring migration (Paton et al. 2021). In addition to nesting and foraging, a number of species regularly stage or stopover on New England's outer islands and travel through the proposed lease areas during migration (Loring et al. 2021). Roseate Terns rely specifically on the region for staging prior to fall migration (Davis et al. 2019).

Little is known about bat occurrence and distribution offshore, but tagging and acoustic studies indicate that cave-hibernating *Myotis* bat species, including the endangered Indiana bat and threatened

[25] NMFS, 2017–2021 North Atlantic Right Whale Unusual Mortality Event. https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2021-north-atlantic-right-whale-unusual-mortality-event.
[26] NMFS, 2016-2021 Humpback whale Unusual Mortality Event along the Atlantic Coast. https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2021-humpback-whale-unusual-mortalityevent-along-atlantic-coast; NMFS, 2017-2021 Minke whale Unusual Mortality Event along the Atlantic Coast. https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2021-minke-whaleunusual-mortality-event-along-atlantic-coast/

northern long-eared bat, and migratory tree bats, including hoary bats, eastern red bats, and silver-haired bats, are present offshore in the Northeast Atlantic region (Peterson et al. 2016).

The waters off southern New England are the most mature site of offshore wind development in the United States. Block Island Wind Farm, comprising a five turbine 30 MW array, became operational in 2016. Eight other areas are currently leased across the RI/MA and MA wind energy areas (WEAs), and the Vineyard Wind I and South Fork wind projects are likely to represent the first commercial-scale wind developments in the U.S., with construction scheduled for 2023.[27] Developers have shown a preference for monopiles in this region, although other fixed foundation types are included in several project design envelopes.

The below recommendations identify several monitoring priorities for the region's species and habitats.[28]

Table 2. Monitoring priorities for Southern New England (Connecticut, Rhode Island, Massachusetts)

Priority Topic	**Scale[29]**	**Time Period**	**Rationale**	**Tools/Techniques**
Disturbance and recovery of complex, hard bottom habitat (including EFH and Habitat Areas of Particular Concern (HAPC))	Local	Pre- and Post-construction /Operation	Complex, hard bottom habitat is important for Atlantic cod, American lobster, and other species. These areas should be mapped pre-construction to inform turbine micro-siting and cable route locations and monitored post-construction and cable laying to assess the rate of recovery and the nature of any habitat change.	Benthic characterization surveys Before-After-Gradient (BAG) studies of (i) of organic enrichment; (ii) distribution, biomass, and abundance of deposit-feeding benthic organisms; (iii) change in infaunal and epibenthic biomass
Distribution and habitat	Local, Sub-regional	Pre-, During, and Post-	Complex, hard bottom substrate is an important habitat for spawning	Acoustic telemetry[30]

[27] https://www.boem.gov/renewable-energy/state-activities.
[28] Data standards for monitoring efforts in this region are currently being defined by the RSWE (Regional Wildlife Science Entity).
[29] Scales are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = Southern New England. To differentiate impacts of offshore wind from impacts from climate change or other factors.
[30] Installation of acoustic receivers in WEAs would also benefit data collection for sea turtles.

Priority Topic	**Scale**[29]	**Time Period**	**Rationale**	**Tools/Techniques**
preferences of spawning cod		construction /Operation	Atlantic cod. Offshore wind development may change this habitat and affect spawning behavior (e.g., avoidance or attraction to the area).	Field examination of fish condition and gravidity Scientific diving/video monitoring for evidence of spawning
North Atlantic right whale foraging habitat-use	Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Understanding the location and extent of right whale foraging areas and how they overlap with wind development areas will enable changes in habitat use/ foraging behavior during and post-construction to be detected. Right whales are a priority as disturbance during foraging could lead to population-level impacts, but data should also be collected and analyzed for other large whale species using the same tools and techniques.	Visual surveys (aerial, vessel-based) Passive acoustic monitoring Environmental sampling, including prey sampling, to inform distribution and movement models
Studies of gull species and diving bird movement and distribution within the Northeast to detect potential future displacement and collision risk	Regional	Pre-, During, and Post-construction /Operation	Studies at wind farms in Europe have shown gulls and diving birds (e.g., sea ducks, loons, Roseate Terns, and Least Terns) to be particularly sensitive to displacement and collision.	Telemetry trackers to understand changes in avian distribution that may result from the presence of turbine platforms creating new habitat Collision detection technology post construction
Building an understanding of the patterns of	Local,	Pre- and Post-	More information is needed on the migration patterns of nocturnal	Automated radio telemetry nanotags

Priority Topic	Scale[29]	Time Period	Rationale	Tools/Techniques
trans-Atlantic landbirds to understand the risks and displacement potential from offshore wind turbines.	Sub-regional, Regional	construction / Operation	migrants (e.g., timing, flight heights, direction) to understand species-specific exposure to potential impacts from offshore wind energy development. This currently presents a data deficit that limits effective management. Particular focus should be paid to the American Golden-Plover, Bicknell's Thrush, Blackpoll Warbler, Bobolink, several species of Sandpipers, Chimney Swift, Whimbler, and Ispwich Sparrow.	(occurrence, flight height, direction) Marine radar (magnitude (i.e., flux), timing, altitude)
Targeted monitoring for beach nesting birds who utilize the area between migratory movements to measure bird displacement and barrier effects. Develop baseline data to understand how offshore wind development impacts migratory bird movements and pathways.	Sub-regional, Regional	Pre- and Post-construction /Operation	Beach nesting birds, like Piping Plover, American Oystercatcher, Black Skimmer, Least Tern, Common Tern, and Roseate Tern, breed along these shorelines in the spring, forage offshore in the spring and summer (tern and skimmer), and travel over water for fall and spring migration. The presence of turbines offshore may negatively impact energy budgets during commuting and migration, and limit access to foraging habitat, potentially resulting in population-level effects.	Avian tracking studies, including automated radio telemetry nanotags and receivers, GPS satellite tags, geolocators and altimeters, as appropriate for the species of concern (e.g., Piping Plover, American Oystercatcher, Black Skimmer, Least Tern, Common Tern, and Roseate Tern) Radar surveys to detect attraction to turbines

Priority Topic	Scale[29]	Time Period	Rationale	Tools/Techniques
				MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial surveys

b. Gulf of Maine

Contributors: *Jocelyn Runnebaum (Region Coordinator) – The Nature Conservancy; Ivy Frignoca – Friends of Casco Bay; Sarah Haggerty & Eliza Donaghue – Maine Audubon; Donald Lyons – National Audubon Society.*

The Gulf of Maine is a semi-enclosed continental shelf bounded by Georges and Browns Bank (Townsend et al., 2010). Nutrient rich waters from the Labrador Current and the warmer saltier Gulf Stream enter through the Northeast Channel and impact the Gulf of Maine's temperature, nutrient availability, and biological productivity (Switzer et al. 2020; Townsend et al. 2010), making it a novel, productive ecosystem for its latitude. However, the Northwest Atlantic Shelf, including the Gulf of Maine, is warming two to three times faster than the global average (Saba et al. 2016). Warming waters are impacting species abundance and distribution in the GOM at all levels of the ecosystem (Hare et al. 2016). Changes in North Atlantic right whale foraging patterns were noticed in 2008 and 2010 due to shifts in their preferred prey (Record et al., 2019). Economically important fish species such as American lobster, scallop, herring, tuna, striped bass and groundfish are all susceptible to the impacts of climate change through impacts to habitat or overall population health (Hare et al. 2016). Boreal nesting seabirds breeding at the southern end of their range in the Gulf of Maine are already experiencing shifts in diet and consequent declines in productivity (Kress et al. 2016).

The Gulf of Maine has several areas demarcated as important habitat in the region. Additionally, in a number of areas that have been identified as important habitat for a variety of species in the Gulf of Maine, fishing activity has either been limited seasonally or prohibited all together (Figure 1). New England Fisheries Management Council protections include deep-sea coral closures, protection for cod spawning grounds, and habitat areas of particular concern for juvenile cod. The Omnibus Deep-Sea Coral Amendment created the Outer Schoodic Ridge Coral Protection Area, the Jordan Basin Dedicated Habitat Research Area, the Mount Desert Rock Coral Protection Area, and the Georges Bank Deep-Sea Coral Protection Area.[31] Bottom-tending mobile gear is prohibited from fishing in the protection areas.[32] NOAA recently established a right whale closed area for the Maine lobster fishery that has not yet gone into effect but has been identified as an important area for North Atlantic right whales in the Gulf of

[31] Omnibus Deep-Sea Coral Amendment | NOAA Fisheries.
[32] https://www.fisheries.noaa.gov/action/omnibus-deep-sea-coral-amendment.

Maine (Figure 2). NOAA also implements a vessel strike prevention program for North Atlantic right whales comprised of regulations and recommendations to reduce vessel strike risk by: 1) reducing the spatial overlap of right whales and vessels, 2) reducing the speed of 4 vessels transiting through right whale habitat, and 3) promoting mariner awareness of right whale presence.

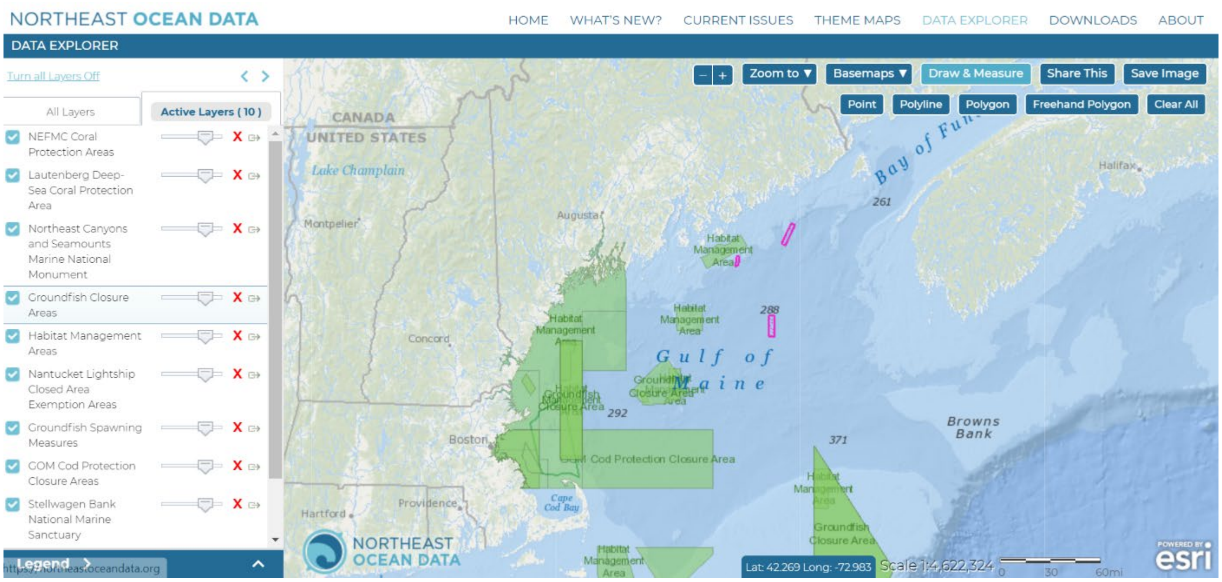

Figure 1. Current closed areas in the Gulf of Maine.

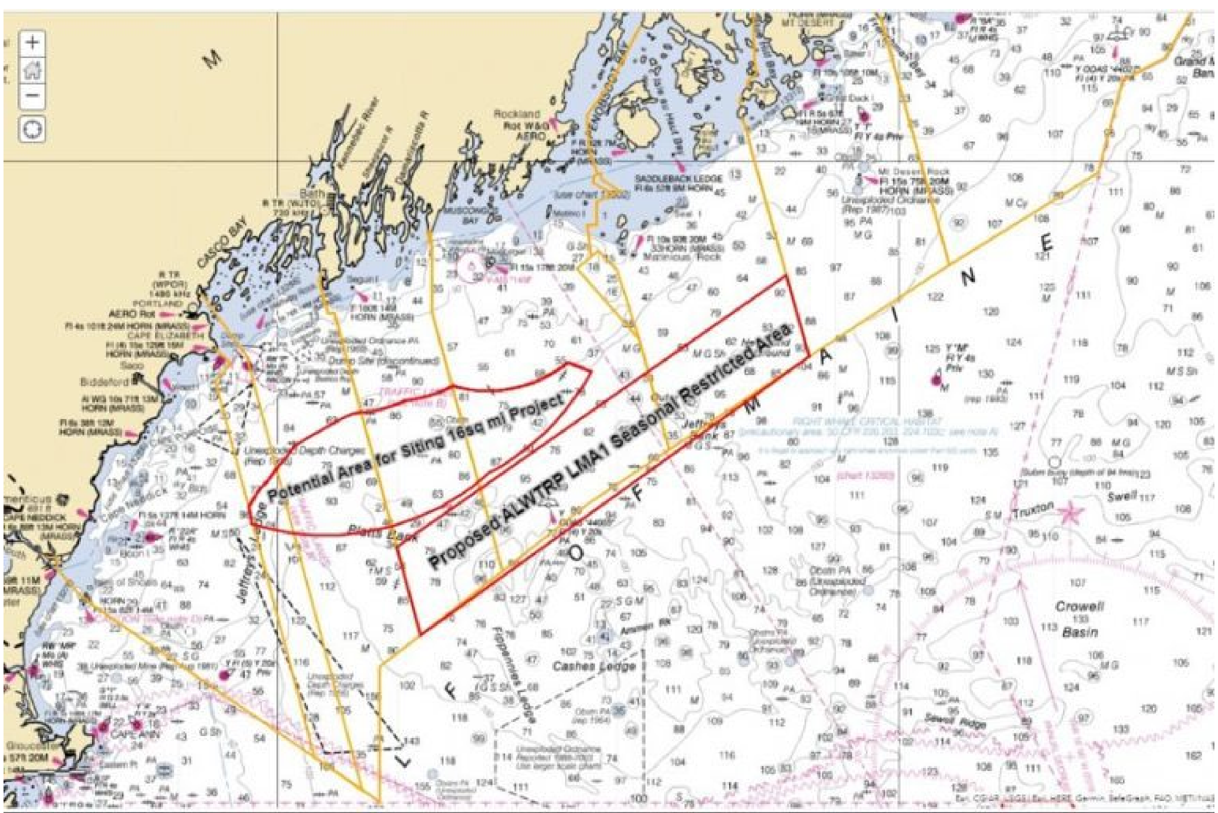

Figure 2. The Lobster Management Area 1 Seasonal Closed Area for North Atlantic Right Whales

The State of Maine has selected a preferred site for a 15 sq mile research array to test floating offshore wind technology in the Gulf of Maine, the lease application was submitted to BOEM October 1, 2021. Conversations to date have indicated that the mostly likely foundation types to be used in the Gulf of Maine is floating technology because of the deep waters in the region. The State of Maine has enacted an offshore wind development moratorium for State waters where fixed turbines could be a potential option. Currently the State of Maine is conducting a Roadmap to Offshore Wind Development to highlight siting considerations, data gaps, and monitoring recommendations.[33]

When designing this regional monitoring plan, an important first step will be identifying already available times series to have the best chance of detecting changes from offshore wind. The first step of the monitoring plan should be a thorough evaluation of the currently available data to guide the development of specific monitoring plans. Below is a list of monitoring priorities for the region.

Table 3. Monitoring priorities for the Gulf of Maine

Priority Topic	Scale[34]	Time Period	Rationale	Tools/Techniques*
Comprehensive seafloor mapping	Gulf of Maine wide	Pre-construction/ Operation	The Gulf of Maine has limited bathymetric data of complex habitats which drives species habitat use and distribution. Complex habitats are important for a number of overfished species in the Gulf of Maine, including Atlantic cod. This information will be critical to siting considerations at both the lease level and the turbine level.	Geophysical surveys using sonar, multibeam
Benthic habitat and species characterization	Larger lease area	Pre-, During, and Post-construction/ Operation	In addition to rocky and complex habitats that are critical to several species, the GOM is also home to several species of deep-sea corals and the extent of their distribution is not	Drop cameras ROVs for post construction impacts

[33] https://www.maineoffshorewind.org/road-map/.

[34] Scales are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = Gulf of Maine. To differentiate impacts of offshore wind from impacts from climate change or other factors.

Priority Topic	Scale[34]	Time Period	Rationale	Tools/Techniques*
			fully known. Benthic habitat characterization pre-construction will be critical to avoiding these ecologically critical species. It will also be important to understand how anchoring systems for floating offshore wind turbines impact benthic habitat and create sediment plumes to provide information for adaptive management if necessary.	
Utilization of benthic habitat by non-commercial species and juvenile stages commercially important juvenile stages	Larger lease area	Pre-, During, and Post-construction/ Operation	Understanding how species utilize complex, benthic habitat at multiple life stages to minimize impacts from offshore wind development. Important species to evaluate include, but not limited to: sand lance, wolffish, Atlantic cod, cusk, sculpins, sedentary invertebrates, and juvenile life stages of fished species.	Will require a variety of tools to monitor transitory fish/invertebrate species. Long term monitoring of species behavior and use of complex habitats. Side-scan sonar for some species Tagging of adults
Icthyoplankton sampling	Gulf of Maine wide	Pre-, During, and Post-construction/ Operation	Plankton are significant indicators of food availability for all species and can be an indicator of distribution shifts for species like North Atlantic Right Whales. By better being able to predict food availability we can start to	Add plankton tows to other sampling platforms Dimethyl sulfide sampling (DMS) – emerging

Priority Topic	Scale[34]	Time Period	Rationale	Tools/Techniques*
			understand when sensitive species might be present to reduce interactions during construction and avoid consistent areas of food availability for placing turbines.	Continuous plankton sampling on ships and buoys
Migratory fish species monitoring	Regional focus	Pre-, During, and Post-construction/ Operation	Understand current migration routes and changes to migratory species behavior once wind arrays are in the water and creating pelagic habitat and EMF that was previously not present. Eels are particularly sensitive to EMF. Other priority species for the Gulf of Maine are: Atlantic salmon, sturgeons, alewife, blueback river herring, shad, and mola mola.	Side-scan sonar, telemetry, satellite tagging Long-term trawl data to help illuminate migratory pathways – use historical data to start to answer this question.
Studies of gull species and diving bird movement and distribution within the Gulf of Maine to detect potential future displacement and collision risk	Regional	Continuous monitoring Pre-, During, and Post-construction/ Operation	Studies at wind farms in Europe have shown gulls and diving birds (e.g., sea ducks and loons) to be particularly sensitive to displacement and collision.	Telemetry trackers to understand changes in avian distribution that may result from the presence of turbine platforms creating new habitat Collision detection technology post construction.
Continued and new surveys to assess species abundance, distribution, and behavior for birds,	Regional	Seasonal monitoring Pre- and Post-	The baseline condition for birds, turtles, mammals, and fish species not captured in	There may be ships of opportunity or new surveys needed. For example, could potentially add

Priority Topic	Scale[34]	Time Period	Rationale	Tools/Techniques*
turtles, mammals, and ecologically important fish species		construction/ Operation	State and Regional trawl surveys is needed for the Gulf of Maine for pre-siting assessments. Mapping efforts from the State of Maine will likely identify data gaps for BOEM to focus efforts on.	marine mammal and bird observers to regional and state fisheries surveys.
Studies of Gulf of Maine nesting boreal species (Atlantic puffins, Arctic Terns, Leach's Storm-petrels, loons, eiders) movement and distribution within the Gulf to detect potential future displacement	Regional	Continuous monitoring Pre-, During, and Post-construction/ Operation	Studies at wind farms in Europe have shown alcids to be particularly sensitive to displacement.	Telemetry trackers to understand displacement
Secondary entanglements for marine mammals, sea birds, fish, turtles, etc.	Project specific	Post-construction/ Operation	Secondary entanglements of marine debris on the mooring lines and inter array cables associated with floating offshore wind technology.	Continuous monitoring and alert systems for removal

c. Mid-Atlantic (Delaware, Maryland, New Jersey, New York, Virginia, and North Carolina)

Contributors: Emily Davis (Region Coordinator) – Natural Resources Defense Council (Independent Contractor); Carl Lobue, Juliet Lamb, Brendan Rue, Susan Bates, & Kate Wilke – The Nature Conservancy; Francine Kershaw – Natural Resources Defense Council; Melissa Edmonds – Southern Environmental Law Center; Jim Murphy – National Wildlife Federation; Garry George – National Audubon Society; Pasha Feinberg – Wildlife and Offshore Wind Coalition (Independent Contractor).

The Mid-Atlantic, defined here as New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina north of Cape Hatteras, is a heavily populated region with complex offshore habitats that host a wide range of speciesenthic habitats are important for breeding, shelter, and feeding of coastal fishes. The Mid-Atlantic encompasses a network of highly productive estuaries that are both bar-built (where accumulated sediments form sand bars at the mouth of the estuary) and coastal plain estuaries (formed from flooded river valleys).[35] Soft sediments, such as those found near shore/estuarine areas, are of high ecological importance (Kritzer el al., 2016). The Mid-Atlantic also features a wide continental shelf with a gradual slope. The shelf seafloor is dominated by a mix of mud, sand and gravel with proportionally less cobble and boulder as compared to the waters off New England.

Submerged aquatic vegetation ("SAV") serves as a key nursery habitat for many species and occurs across the Mid-Atlantic, and eelgrass is a particularly important species that has experienced decline and restoration.[36] SAV occurs in nearshore environments within the estuaries, and its presence and growth are affected by water clarity, eutrophication, and warming waters.[37]

Estuarine and shelf surface waters in the Mid-Atlantic exhibit globally significant seasonal water temperature extremes with deeper shelf waters characteristically establishing a seasonal stratification feature commonly referred to as the "Cold Pool." The Cold Pool is a highly variable 20-60 m thick band of trapped cold, near-bottom water that exists during the spring, summer, and fall in the mid- and outer-shelf of the Mid-Atlantic Bight and Southern flank of Georges Bank. Mid-Atlantic rivers and estuaries that feed into the offshore environment provide large amounts of nutrients in addition to those available through wind driven upwelling in and around the Cold Pool (Miles et al., 2021).

The Cold Pool has been shown to be one of several factors affecting phytoplankton productivity and the behavior and recruitment of pelagic and demersal fish (Malone et al., 1983; Sullivan et al., 2005), including black sea bass, tautog, monkfish, spiny dogfish, and assorted skate species (Miles et al., 2021). In particular, several species of flounder are known for an inshore-offshore migration from the Chesapeake Bay to the Cold Pool (Miles et al., 2021). This inshore to offshore migration relies on the relationship between the estuaries and the Cold Pool, and it is compounded by the reliance of these species on soft-bottomed benthic habitats. Due to the Cold Pool's effects on forage fish, an important prey base for marine mammals, diving birds, and other marine predators across this region, it is a critical oceanographic process to consider and monitor. The Cold Pool has been observed shrinking as well as warming as part of the greater shifts in the global climate. This, combined with the observed southward shift in the weakening Gulf Stream, represents changes that are expected to amplify rising water levels and contribute to significant shifts in weather patterns (Gangopadhyay et al., 2019).[38]

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[35] NOAA, Classifying Estuaries: By Geology. https://oceanservice.noaa.gov/education/tutorial_estuaries/est04_geology.html#:~:text=Credit%3A%20NASA)-,Bar%2Dbuilt%20Estuaries,during%20most%20of%20the%20year.

[36] VIMS, SAV Restoration on the Seaside of VA's Eastern Shore (last visited Aug. 2, 2021).

[37] Synthesis of U.S. Geological Survey Science for the Chesapeake Bay Ecosystem and Implications for Environmental Management. https://pubs.usgs.gov/circ/circ1316/html/circ1316chap11.html.

[38] NOAA Fisheries, State of the Ecosystem. https://apps-nefsc.fisheries.noaa.gov/rcb/publications/soe/SOE-MAFMC_2022_Final.pdf.

The Mid-Atlantic is host to a variety of species, including both long-term residents as well as more mobile migrants. These species include tuna, sharks, marine mammals, sea turtles, and a range of avian species. Protected under the Endangered Species Act ("ESA"), Atlantic sturgeon are found in the coastal Mid-Atlantic, and they use the Hudson River in New York as well as several rivers in Virginia for spawning.[39,40] Shortnose sturgeon, giant manta ray, oceanic whitetip sharks, and scalloped hammerhead shark all occur in the Mid-Atlantic and are also protected by the ESA. Animals engaging in migration can either be found moving north-south or shifting from inshore to offshore, and many species rely on the Mid-Atlantic for foraging areas.

Numerous large whales (including fin, sei, blue, sperm, and North Atlantic right whales) are listed as endangered under the ESA and as depleted and strategic stocks under the Marine Mammal Protection Act, and many have either a permanent or migratory presence in the Mid-Atlantic. North Atlantic right whale distributions and habitat have been observed shifting since 2010 as a response to climate change and prey availability (Meyer-Gutbrod et al., 2018). This shift represents an increased amount of time in the Mid-Atlantic and the species is now displaying a year-round presence in areas of the Mid-Atlantic,[41] including the New York Bight and Virginia (Davis et al., 2017; Estabrook at al., 2019).[42,43] Humpback and fin whales may occur year-round in the New York Bight, their numbers are increasing, and they are regularly observed forming large multi-species foraging aggregations (Whitt et al., 2015).[44] Nearshore Mid-Atlantic waters, including those off Virginia, serve as an important migratory area for humpback and endangered fin whales, while more offshore waters may represent migratory habitat for minke and endangered sei whales.[45] While they are not currently listed as depleted, ongoing UMEs (unusual mortality events) exist for the Atlantic populations of both minke whales (since January 2017) and

[39] Endangered and Threatened Species; Designation of Critical Habitat for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon and the Threatened Gulf of Maine Distinct Population Segment of Atlantic Sturgeon, 82 Fed. Reg. 39,160 (Aug. 17, 2017).

[40] NY Department of Environmental Conservation. The Atlantic Sturgeon: The Symbol of The Hudson River Estuary. https://www.dec.ny.gov/lands/5084.html#:~:text=Atlantic%20sturgeon%20spend%20most%20of,Canada%20and%20south%20to%20Georgia.

[41] NMFS, Section 7 Species Presence Table: Atlantic Large Whales in the Greater Atlantic Region (last visited June 22, 2021), https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-species-presence-table-atlantic-large-whales.

[42] This was supported by the findings of the New York State Department of Environmental Conservation (NYSDEC) aerial surveys conducted in the New York Bight monthly from March 2017 through February 2020. There, right whales were sighted during every season except summer. Tetra Tech and LGL. 2020. Final comprehensive report for New York Bight Whale Monitoring Aerial Surveys, March 2017 – February 2020. Technical report prepared by Tetra Tech, Inc. and LGL Ecological Research Associates, Inc. Prepared for New York State Department of Environmental Conservation, Division of Marine Resources, East Setauket, NY.

[43] NAT'L OCEANIC AND ATMOSPHERIC ADMIN. (NOAA), Ecology of the Northeast US Continental Shelf: Zooplankton (last visited June 22, 2021), https://www.nefsc.noaa.gov/ecosys/ecosystem-ecology/zooplankton.html.

[44] Pierre-Louis, K. 2017. "Why Whales are Back in New York City." Popular Science. June 7. Available at: https://www.popsci.com/new-york-city-whales#page-4.

[45] https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-species-presence-table-atlantic-large-whales.

humpback whales (since January 2016).[46] The Mid-Atlantic is also home to a wide array of small cetacean species, including several depleted and strategic stocks,[47] sirenians, and pinniped species. While manatee species occur relatively infrequently, it should be noted that several species of dolphins as well as harbor porpoises have an established presence in Mid-Atlantic waters. [48]

Sea turtles are found throughout the Mid-Atlantic. In the New York Bight, four sea turtle species are known to occur: the endangered Kemp's ridley and leatherback turtles and the threatened green and loggerhead turtles.[49] Loggerheads occur north of Cape Hatteras primarily in late spring through early fall (May and October) with a peak occurrence in June; however, sightings are recorded in Mid-Atlantic and Northeast waters throughout the year.[50] In addition to general presence, Virginia and North Carolina are important nesting habitats during the spring and summer months. While leatherback sea turtles are found in Virginia waters year round, most species can be found there from May through October or November.[51] It should be noted that the warming water temperatures are contributing to changes in the distributions of these species. Sea turtles have been observed lingering around Long Island as late as December, though they experience cold stunning as a result of sudden temperature drops.[52]

The Mid-Atlantic serves multiple purposes for avian species. As part of the Atlantic flyway, birds have a strong migratory presence, both moving from inshore to offshore as well as from north to south. Red Knots and Piping Plover, both protected under the ESA, as well as other shorebirds are regularly found across the Mid-Atlantic coast. Beach nesting birds, like Piping Plover, American Oystercatcher, and Black Skimmer, cut across the Mid-Atlantic Bight to reach breeding grounds along New York and New England in the spring and on their return flights south. Other birds that occur around the Atlantic outer continental shelf include Least Terns, Roseate Terns, and several other species of terns and gulls that breed along the Atlantic coast, as well as multiple seabird species including petrels, shearwaters, sea ducks, loons, gannets, and alcids that breed outside the area but travel to the waters of the Mid-Atlantic to forage or overwinter. Nocturnally migrating passerines from across North America similarly convene along New Jersey's coast prior to beginning their southward trans-Atlantic migration in the fall, and they often cross the New York Bight from stopover locations on Long Island before making landfall along the New Jersey Coast. Long Island Sound and offshore areas near the mouths of the Chesapeake and Delaware Bays are particularly important foraging hotspots for overwintering diving birds including

[46] UMEs can include unexpected strandings or die-offs in the population (these can happen due to a variety of reasons including but not limited to disease, malnutrition, rope entanglement, vessel strikes, and other ecological factors). https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events.
[47] US Atlantic and Gulf of Mexico
Marine Mammal Stock Assessments 2020 https://media.fisheries.noaa.gov/2021-07/Atlantic%202020%20SARs%20Final.pdf?null%09.
[48] NOAA Species Directory. https://www.fisheries.noaa.gov/species-directory/marine-mammals?species_category=any&species_status=any&regions=1000001111&items_per_page=all&sort=.
[49] New York State Department of Environmental Conservation, "Sea Turtles of New York." https://www.dec.ny.gov/animals/112355.html.
[50] Section 7 Species Presence Table: Sea Turtles in the Greater Atlantic Region https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-species-presence-table-sea-turtles-greater.
[51] Section 7 Species Presence Table: Sea Turtles in the Greater Atlantic Region https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-species-presence-table-sea-turtles-greater.
[52] https://www.dec.ny.gov/animals/112355.html.

Northern Gannets, Common and Red-throated Loons, and Black, Surf, and White-Winged Scoters. The Eastern Shore peninsula from Virginia to Delaware is classified as an Important Bird Areas (IBA) that are used by birds for both nesting and migration. Red Knots and Piping Plovers are present in this area, as are Black Skimmers and American Oystercatchers.

Like other regions, little is known about bat occurrence and distribution offshore. Limited tagging and acoustic research from the region indicates that both cave-hibernating *Myotis* bat species and migratory tree bats are present offshore in the Mid-Atlantic region, and bat calls were detected as far as 130km offshore (Peterson et al., 2016). Additionally, nine species of bats are found in the New York – New Jersey area: including cave-hibernating resident bats like the little brown bat, northern long-eared bat, eastern small-footed bat, Indiana bat, tricolored bat, and the big brown bat.[53]

As of October 2022, the area has 18 existing commercial OSW lease areas covering around 1.42 million acres excluding right of ways for transmission cables (and additional areas are currently in the process of being identified, see more below).[54] Current Mid-Atlantic offshore Wind Energy Areas are landward of the 60-meter depth contour and thus exclude the shelf-slope break and the highly productive offshore canyons. In 2022, BOEM initiated a process to identify additional lease areas in the Central Atlantic encompassing an area offshore Delaware south to Cape Hatteras and extending in some areas offshore of the shelf break.[55] Previously, the presence of offshore wind in the region was limited to two turbines in the Coastal Virginia Offshore Wind project.

Table 4. Monitoring priorities for the Mid-Atlantic

Priority Topic	**Scale[56]**	**Time Period**	**Rationale**	**Tools/Techniques**
Altered hydrodynamics with particular emphasis on stratification and mixing	Local, Sub-regional, Regional	Pre- and Post-construction	While this is a monitoring priority across regions, the importance of the Cold Pool to the regional climate makes it a priority issue for the Mid-Atlantic region. The ability to detect active effects on the Cold Pool due to the presence of turbines, is limited, however, local data can provide essential	In situ measurements of hydrodynamics (e.g., wake analysis, temperature at different depths) Hydrodynamic model predictions

[53] Bats of New York, https://www.dec.ny.gov/docs/administration_pdf/batsofny.pdf; New Jersey Agricultural Experiment Station: The Facts About Bats in New Jersey, https://njaes.rutgers.edu/fs1207/.
[54] https://www.boem.gov/renewable-energy/state-activities/central-atlantic.
[55] https://www.boem.gov/renewable-energy/state-activities/central-atlantic-activities.
[56] Regions are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = Mid-Atlantic. To differentiate impacts of offshore wind from impacts from climate change or other factors.

Priority Topic	**Scale**[56]	**Time Period**	**Rationale**	**Tools/Techniques**
			modeling information that can add context to the existing changes due to overarching shifts in climate. Cumulatively this may result in broader scale changes (e.g., altered stratification) that may affect settlement, recruitment, and connectivity, including for key prey species. Species such as yellowtail flounder, summer flounder, winter flounder, windowpane flounder, witch flounder, fourspot flounder, black sea bass, tautog, monkfish, and spiny dogfish, and tautog recruitment and habitat availability are directly linked to the strength of the Cold Pool (Miles et al., 2021).[57]	
Mapping Total Suspended Matter (TSM) for resuspended sediment particles in turbine wakes.	Sub-regional	Post-construction /Operation	Increased marine turbidity can impact primary producers such as phytoplankton as well as the vision capabilities of larger marine animals and has a risk of causing bathymetric changes as well as overall light	Digital mapping and analysis using available remote sensing and satellite imagery of the affected area

[57] In existing studies, individual turbines have been found to alter local hydrodynamics (turbulence, eddies). Because of the relationship between estuaries and the marine environment in the Mid-Atlantic, monitoring should extend to areas affected by output from estuaries or river mouths.

Priority Topic	Scale[56]	Time Period	Rationale	Tools/Techniques
			abundance (Vanhellemont and Ruddick 2014).[58]	
Utilization of soft bottomed benthic habitat and near shore habitat by commercial and non-commercial fish species.	Larger lease area	Pre-, During, and Post-construction /Operation	Fish species that rely on soft bottom substrates may face potential habitat disruption or modification from offshore wind energy foundation construction while species that rely on hard bottom substrates may find an increase in habitat. Potential interactions between shifting habitats and other factors such as localized dredging (such as reduced fishing in the area possibly mitigating habitat loss) or the wider spread effects of climate change are not known. There is a need to understand how species utilize the regional benthic habitat at multiple life stages is important to minimize impacts from offshore wind development across longer time scales. Important species to evaluate include: yellowtail flounder, summer flounder, winter flounder, windowpane flounder, witch flounder, fourspot flounder, black	Will require a variety of tools to monitor transitory fish/invertebrate species. Long term monitoring of species behavior and use of complex habitats Side-scan sonar for some species Tagging of adults

[58] Around the Thames Estuary in the UK, turbine wakes displaying increased turbidity have extended one or more kilometers away from the offshore wind farms in length (The Thanet wind farm showed wakes greater than 10km in length) while their width was 30-150m (Vanhellemont and Ruddick 2014).

Priority Topic	Scale[56]	Time Period	Rationale	Tools/Techniques
			sea bass, tautog, monkfish, and spiny dogfish, sedentary invertebrates, and juvenile life stages of fished species.	
Migratory fish species monitoring, for both north-south as well as inshore-offshore migrations	Regional focus	Pre-, During, and Post-construction /Operation	Understand current migration routes and changes to migratory species behavior once wind arrays are in the water and creating new habitat through mid-water structures and EMF that was previously not present. For north-south movement, particular species of concern should be: sturgeons, menhaden, chub mackerel, spiny dogfish, and Atlantic mackerel. For inshore-offshore movement, monitoring efforts should consider: yellowtail flounder, summer flounder, winter flounder, windowpane flounder, witch flounder, fourspot flounder, black sea bass, and tautog.[59]	Side-scan sonar, telemetry, satellite tagging Long-term trawl data to help illuminate migratory pathways – use historical data to start to answer this question
Large whale habitat-use during migrations and foraging	Sub-regional, Regional	Pre-, During, and Post-construction	Understanding the location and extent of large whale foraging areas, including multi-species aggregations that may also involve birds, dolphins, fish and how they overlap with wind	Visual surveys (aerial, vessel-based) Passive acoustic monitoring Environmental sampling to inform

[59] Additional EMF specific monitoring recommendations on p. 11.

Priority Topic	**Scale**[56]	**Time Period**	**Rationale**	**Tools/Techniques**
			development areas will enable detection of changes in habitat use/ foraging behavior during and post-construction.	distribution and movement models
Sea turtle movements, distribution, and habitat use patterns	Local, Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Studies to understand and determine if/ how wind development areas, wind-related vessel traffic, and onshore connection points may impact location and distribution of sea turtles (in-water) and nesting locations and to detect any potential change in habitat use/ behavior during and post-construction/operation. Additional information on movement, dive patterns, and surface time would also improve impact assessments and help advise monitoring and mitigation strategies. Sea turtle species known to occur in the Mid-Atlantic include: Kemp's ridley, leatherback turtles, green turtles, and loggerhead turtles.	Acoustic telemetry of wild caught and rehabilitated sea turtles[60] Satellite telemetry Aerial surveys (visual, digital)
Studies of marine bird movement and distribution within the Mid-Atlantic to detect potential future displacement and collision risk	Regional	Pre-, During, and Post-construction /Operation	Studies at wind farms in Europe have shown marine birds that forage in pelagic and nearshore environments (e.g., Northern Gannet, Common Loon, Red-Throated Loon, Black	Telemetry trackers to understand changes in avian distribution that may result from the presence of turbine platforms creating new habitat

[60] Installation of acoustic receivers in WEAs would also benefit data collection for fish.

Priority Topic	Scale[56]	Time Period	Rationale	Tools/Techniques
			Scoter, Surf Scoter White-Winged Scoter, Long-tailed Duck, Band-rumpled Storm Petrel, Leach's Storm Petrel, Northern Fulmar, Black-capped Petrel Cory's Shearwater, Manx Shearwater, Audubon's Shearwater, Razorbill, Atlantic Puffin, and Dovekie) to be particularly sensitive to displacement and collision. Other species, particularly large-bodied gulls (Herring Gull, Great Black-backed Gull) and cormorants, have shown attraction to wind farm sites. For these species, offshore wind farms may represent potential enhanced foraging habitat for birds, furthering their attraction to them, and increasing their risk of collision.	Collision detection technology post construction
Building an understanding of the patterns of trans-Atlantic landbirds to understand the risks and displacement potential from offshore wind turbines	Local, Sub-regional, Regional	Pre- and Post-construction /Operation	More information is needed on the migration patterns of nocturnal migrants (e.g., timing, flight heights, direction) to understand species-specific exposure to potential impacts from offshore wind energy development. This currently presents a data deficit that limits effective management. Particular	Automated radio telemetry nanotags (occurrence, flight height, direction) Marine radar (magnitude (i.e., flux), timing, altitude) Acoustic monitoring of flight calls (for birds with sufficient vocalizations)

Priority Topic	Scale[56]	Time Period	Rationale	Tools/Techniques
			focus should be paid to the American Golden-Plover, Bicknell's Thrush, Bobolink, several species of Sandpipers, and Whimbrels.	
Targeted monitoring for beach nesting birds who utilize the area between migratory movements to measure bird displacement and barrier effects. Develop baseline data to understand how offshore wind development impacts migratory bird movements and pathways.	Sub-regional, Regional	Pre- and Post-construction /Operation	Beach nesting birds, like Piping Plover, American Oystercatcher, Black Skimmer, Least Tern, Common Tern, Fosters Tern, Royal Tern, and Roseate Tern, breed along these shorelines in the spring, forage offshore in the spring and summer (tern and skimmer), and travel over water for fall and spring migration. The presence of turbines offshore may negatively impact energy budgets during commuting and migration, and limit access to foraging habitat, potentially resulting in population-level effects.	Avian tracking studies, including automated radio telemetry nanotags and receivers, GPS satellite tags, geolocators and altimeters, as appropriate for the species of concern (e.g., Piping Plover, American Oystercatcher, Black Skimmer, Least Tern, Common Tern, and Roseate Tern) Radar surveys to detect attraction to turbines MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial surveys

d. South Atlantic (North Carolina, South Carolina, Georgia, and Florida)

Contributors: Mary Conley (Region Coordinator) – The Nature Conservance; Emily Davis (Independent Contractor) – Natural Resources Defense Council; Francine Kershaw – Natural Resources Defense Council; Melissa Edmonds – Southern Environmental Law Center; Pasha Feinberg – Wildlife and Offshore Wind Coalition (Independent Contractor).

The South Atlantic represents an area of the Atlantic Ocean extending from Cape Hatteras, NC to Cape Canaveral, FL. It is known for its vast intertidal wetland habitats, warm waters, and broad, shallow coastal shelf bounded by the Gulf Stream. Also described as the Carolinian Ecoregion or South Atlantic Bight, it is a transition zone between the subtropical waters of south Florida and the cool, temperate waters of the Mid-Atlantic (Spalding et al. 2007).

The shoreline between Cape Hatteras and Cape Canaveral supports some of the largest expanses of coastal wetlands in the United States, including a band of salt marsh and complex network of tidal creeks up to 12 km wide. Significant freshwater flow from large river systems, including Cape Fear, Pee Dee, Santee, Savannah and Altamaha, and large tidal range support these extensive intertidal wetland habitats which are particularly well developed along the South Carolina and Georgia coasts (Dame et al. 2000; Rogers et al. 1984). Salt marshes and the network of tidal creeks and pools within them provide forage opportunities and important nursery grounds for shellfish, finfish and shorebirds.

One key feature of the Carolinian Ecoregion is the large, shallow continental shelf, 40 to 85 miles (60 to 100 km) wide and 5 to 100 m deep. The topography of the shelf is mostly flat, covered by a sheet of sand-shell bottom with some mud bottom areas located closer to the coast. Low relief features such as sandy shoals and deltas are associated with coastal capes and rivers. The Continental Shelf is underlain in places by a hard limestone pavement; corals and other species form diverse colonies in places where the limestone is exposed. Rocky outcrops scattered across the region are particularly prominent in depths from 45 to 60 m (Fautin et al. 2010), where they support an array of sessile invertebrates and algae, creating high-biomass, diverse, hard bottom habitats. Associated with these habitats is a diverse assemblage of warm-temperate and subtropical reef fish, including snapper, grouper, grunt, porgy, and wrasse. There are five marine protected areas (MPAs) in the area directed towards protecting this fish group and deep-water coral habitats.[61]

Both the Charleston Bump and the associated Blake Plateau form essential habitat for multiple species of fish, in part due to the caves and rocky outcroppings as well as the unique currents that results from the deflection of the Gulf Stream which forms the Charleston Gyre; together they create an important foraging and spawning habitat used by demersal and deep-water fish including skates, sharks, flounders, groupers, bass and more.[62] Associated with the shelf break are a number of canyons and channels which

[61] NOAA MPAs for the region, www.fisheries.noaa.gov/southeast/marine-protected-areas-group-southeast
[62] Species presence and habitat use is still poorly understood, and most species' presences are observed by wreckfish fishermen or observed by submersible.

have recently been explored. The area is seasonally protected from fishing to prevent bycatch from non-targeted species in the area.[63]

The northward flowing Gulf Stream travels along the shelf edge and meets the southward flowing waters of the Mid-Atlantic at Cape Hatteras. The collision of cool and warm waters results in upwelling of nutrient-rich water which supports a variety of birds, marine mammals, pelagic fish, and bottom communities (Savidge and Austin, 2007).

While the South Atlantic shares many conditions and migratory fish species with neighboring regions such as the Mid-Atlantic, it is characterized as a transition point from cooler temperate waters to warmer subtropical conditions, which in turn leads to both temperate and sub-tropical fish having an established presence in the region. Additionally, the Gulf Stream spans the region and is a recognized essential fish habitat (EFH) with many smaller EFHs for both reefs, and marine species such as wahoo, golden crab, shrimp, spiny lobster, tilefish, and the snapper grouper complex.[64] There are multiple ESA protected fish including Atlantic and shortnose sturgeon, largetooth and smalltooth sawfish, and scalloped hammerheads.[65] Species that are considered threatened under the ESA are giant manta rays, gulf sturgeon, Nassau grouper, and oceanic whitetip sharks.[66] While shortfin mako sharks are not listed, they occur in the region and have populations that are below target levels. A fish species with a significant presence in the region is red grouper. They are considered "ecosystem engineers", seeking out holes in limestone structures where they will clear sediment and rocky debris using their fins. This creates clear spaces with rocky substrate which becomes habitat for invertebrates such as coral and sponges and entire communities form around them in turn.[67]

American eels have shown a steady decline across multiple decades. The distribution of American eels in the riparian and estuarine systems of the southeast United States creates a regional migration across the Southeast Atlantic as they move towards the Sargasso Sea to spawn. However, much of their behavior and distribution around migration, spawning, and larval development is still unknown. They have, however, been observed congregating in the Sargasso Sea, a thick layering of *Sargassum* vegetation that is hemmed in by the Sargasso Gyre, a system of currents that spans the greater part of the North Atlantic Ocean between the United States and Europe and Africa. The exact borders of where the *Sargassum* occurs are continuously shifting, but it has a steady presence near the United States' South Atlantic coastline due to its regular presence near Bermuda.

[63] NOAA Profile on the Charleston Bump, https://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup11_bump.html#:~:text=It%20is%20a%20deep water%20bank,rocky%20cliffs%2C%20overhangs%20and%20caves.

[64] SAFMC map of essential fish habitat, https://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=961f8908250a404ba99fac3aa37ac723.

[65] NOAA directory of threatened and endangered species, http://www.fisheries.noaa.gov/species-directory/threatened-endangered?title=&species_category=1000000031&species_status=esa_endangered&regions=1000001121&items_per_page=25&sort=.

[66] NOAA directory of threatened and endangered species, http://www.fisheries.noaa.gov/species-directory/threatened-endangered?title=&species_category=1000000031&species_status=esa_endangered&regions=1000001121&items_per_page=25&sort=.

[67] NOAA profile on Red Grouper https://www.fisheries.noaa.gov/species/red-grouper.

Three sub-groups of marine mammals are found in the South Atlantic region: cetaceans, sirenians and pinnipeds. The fin, humpback, North Atlantic right, sei, and sperm whales are listed as endangered under the ESA and the Florida manatee is listed as threatened. The South Atlantic region has significant populations of *Delphinidae* species, including multiple MMPA depleted stocks of bottlenose dolphins, and significant numbers of common dolphin as well as numerous oceanic dolphins.[68] Florida manatees occur across the region, and are dependent on sea grasses and algae for foraging. Multiple species are experiencing unusual mortality events (UME) within the region area including North Atlantic right, minke, humpback whales, and manatees.[69]

The North Atlantic right whale is considered to be one of the most critically endangered large whales in the world and could be facing extinction (Pettis et al. 2021). The South Atlantic region supports the species' only calving ground in the shallow waters off northern Florida, Georgia, and the Carolinas. There are three cetacean biologically important areas (BIA) for the region: the North Atlantic right whale calving ground and broader migratory habitat that spans the east coast continental shelf, and estuarine habitat that supports a year-round bottlenose dolphin habitat across the region.[70] Habitat density models predict higher density of several baleen whale species near the shelf break and Gulf Stream; however, there is limited sighting and telemetry data in these areas (Curtice et al. 2019).

Five sea turtle species, green turtle, Kemp's ridley, loggerhead, leatherback and hawksbill, are found in the South Atlantic region. The Kemp's ridley, hawksbill and leatherback sea turtles are listed as endangered under the ESA, and the Northwest Atlantic loggerhead population and the North Atlantic green sea turtle population are listed as threatened.[71] These species use a range of habitats across the region at a variety of ecological stages. Beaches from southern Virginia to Florida are important nesting areas (Conant et al. 2009); however, information on presence and timing of activities offshore and outside of nesting periods is less known.

A wide variety of birds utilize the coastal systems of the South Atlantic for breeding, overwintering, migration and foraging, with numerous globally recognized important bird areas (IBAs).[72] For example, salt marshes, coastal swamps, and sandy beaches within the South Atlantic Bight serve as critical nesting habitat for migratory species such as wood storks and American oystercatchers. Cape Romain National Wildlife Refuge and Georgia Barrier Islands demonstrate the value of these habitats. Designated as Western Hemisphere Shorebird Reserve Network (WHSRN) sites, they support over 20 species of shorebirds[73] In addition, Piping Plover and Rufa Red Knot, listed as threatened under the ESA (USFWS,

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[68] NOAA directory of threatened and endangered species, http://www.fisheries.noaa.gov/species-directory/threatened-endangered?title=&species_category=1000000031&species_status=esa_endangered&regions=1000001121&items_per_page=25&sort=.

[69] NOAA list of current and previous unusual mortality events (UMEs), https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events.

[70] Map of biologically important areas, https://cetsound.noaa.gov/biologically-important-area-map.

[71] NOAA Sea Turtle Recovery Plans

[72] Important Bird Areas in the South Atlantic, https://www.audubon.org/important-bird-areas/state/florida; https://www.audubon.org/important-bird-areas/state/georgia; https://www.audubon.org/important-bird-areas/state/north-carolina; https://www.audubon.org/important-bird-areas/state/south-carolina.

[73] WHSRN overviews of Cape Romain – Santee Delta, and Georgia Barrier Islands, https://whsrn.org/whsrn_sites/cape-romain-santee-delta-region/; https://whsrn.org/whsrn_sites/georgia-barrier-islands/.

1996)[74] Less information is available on bird presence and use away from the coast. Limited monitoring data is available for sea birds; of what exists, models show relatively high abundances of Black-Capped Petrel, Audubon's Shearwater, Bridled Tern, Cory's Shearwater.[75]

Little is known about bat occurrence and distribution offshore; tagging and acoustic studies done in other regions, such as the neighboring Mid-Atlantic, are limited in the South Atlantic. Studies, mostly in other regions, have indicated that both cave-hibernating bat species (a guild which includes *Myotis* spp., such as the endangered Indiana bat and the endangered Northern long-eared bat[76]), and migratory bat species are found offshore, with recent acoustic surveys finding bats 130 km offshore (Peterson et al., 2016). Although most of the limited research on bat movements offshore were done outside of the South Atlantic, the species detected offshore in other regions are also found in the South Atlantic and ostensibly could be present offshore in the region.

The first offshore wind lease sale in the South Atlantic, in Carolina Long Bay, was on May 11, 2022, where two lease areas with a total acreage of 110,091 were auctioned. Much of the monitoring effort along the Atlantic has been focused on the Northeast and Mid-Atlantic, where offshore wind energy development is further advanced.

The South Atlantic has benefited from some coastwide analyses and models, related to marine mammals and birds; however, the data available to incorporate into those analyses may be insufficient capture annual and seasonal changes exhibited in the region. The below recommendations identify several monitoring priorities for the region's species and habitats.

Table 5. Monitoring priorities for South Atlantic (Cape Hatteras to Cape Canaveral)

Priority Topics	**Scale[77]**	**Time Period**	**Rationale**	**Tools/Techniques**
Seafloor habitat characterization	Regional, Local	Pre-, During, and Post-construction/ Operation	The South Atlantic has unique habitat features such as underwater ridges, shoals, channels, canyons, and hard bottom patches that	Benthic transects and sampling, water column net sampling Visual surveys using ROV/AUV

[74] Federal Register Notice: Designation of Critical Habitat for Rufa Red Knot, 2021.
[75] Atlantic Marine Bird Cooperative https://atlanticmarinebirds.org/#:~:text=Atlantic%20Marine%20Bird%20Cooperative,ecosystems%20of%20Eastern%20North%20America.
[76] The Northern long-eared bat was recently reclassified from Threatened to Endangered status under the ESA. *See* 87 Fed. Reg. 73,488 (Nov. 30, 2022)
[77] Regions are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = South Atlantic. To differentiate impacts of offshore wind from impacts from climate change or other factors.

Priority Topics	Scale[77]	Time Period	Rationale	Tools/Techniques
			separate it from other regions and create a chain of critical habitats for ecologically and economically important species including snapper-groupers, coral, skates, sharks, flounders, bass, and high numbers of invertebrates. While some of these areas such as the Charleston bump have had some mapping performed, the area in general is a data deficient region that needs additional study.	Benthic characterization surveys and mapping to correlate species and habitat health Sonar, side-scan sonar
Disturbance and recovery of complex, hard bottom habitat	Local	Pre- and Post-construction/ Operation	Complex, hard bottom habitat is important for snapper and grouper, and several other species. These areas should be mapped pre-construction to inform turbine micro-siting and cable route locations and monitored post-construction and cable laying to assess the rate of recovery and the nature of any habitat change.	Benthic characterization surveys Before-After-Gradient (BAG) studies of (i) of organic enrichment; (ii) distribution, biomass, and abundance of deposit-feeding benthic organisms; (iii) change in infaunal and epibenthic biomass

Priority Topics	**Scale[77]**	**Time Period**	**Rationale**	**Tools/Techniques**
Assess species abundance, distribution, and behavior for ecologically important fish species who rely on the complex habitat of the South Atlantic	Regional, Local	Seasonal monitoring Pre- and Post-construction/ Operation	The baseline condition for fish species in the South Atlantic is not well captured and models have been developed with limited sightings data. Species included in this monitoring should be members of the snapper-grouper complex, sharks, and skates.	Visual surveys (aerial, vessel-based) Telemetry and tracking studies Side-scan sonar for some species. Tagging of adults
Migratory fish species monitoring	Regional	Pre-, During, and Post-construction/ Operation	There is a need to understand current migration routes and changes to migratory species behavior once wind arrays are in the water and creating pelagic habitat and EMF that was previously not present. Eels are particularly sensitive to EMF. Other priority species for the South Atlantic are sturgeons, alewife, shad, and American eel.	Side-scan sonar Telemetry Satellite tagging Long-term trawl data to help illuminate migratory pathways (*i.e.*, use historical data to start to answer this question)
North Atlantic right whale calving areas and migratory pathways	Regional, Local	Pre-, During-, and Post-Construction/ Operation	Development of offshore wind in critical habitat may impact North Atlantic right whale calving success and population recovery. Understanding the	Visual surveys (aerial, vessel-based) Passive acoustic monitoring

Priority Topics	**Scale**[77]	**Time Period**	**Rationale**	**Tools/Techniques**
			location and extent of NARW calving areas and migratory pathways, and evaluating shifts due to climate change, will be key to informing risk assessment and siting decisions. Monitoring to detect any short- or long-term potential change in habitat use associated with site assessment, construction and operations is also critical if impacts to the species are to be minimized and mitigated.	Environmental sampling to inform distribution and movement models
Impact of construction and cable-laying on bottlenose dolphins	Local	Pre-, During-, and Post-Construction	Assess and study the overlap and potential impact of turbine construction and cable-laying on bottlenose dolphin stocks in wind development areas, including onshore connection areas during and post-construction.	Visual surveys (aerial, vessel-based) Passive acoustic monitoring
Sea turtle movements, distribution, and habitat use patterns	Local, Sub-regional, Regional	Pre-, During, and Post-construction/ Operation	Studies to understand and determine if/ how wind development areas, including EMF, wind-related vessel traffic, and onshore	Acoustic telemetry of wild caught and rehabilitated sea turtles Satellite telemetry

Priority Topics	**Scale[77]**	**Time Period**	**Rationale**	**Tools/Techniques**
			connection points may impact location and distribution of sea turtles (in-water) and nesting locations and to detect any potential change in habitat use/ behavior during and post- construction/ operation. Additional information on movement, dive patterns, and surface time would also improve impact assessments and help advise monitoring and mitigation strategies. Sea turtle species known to occur in the Southeast include green, Kemp's ridley, loggerhead, leatherback and hawksbill turtles.	Aerial surveys (visual, digital)

Priority Topics	**Scale**[77]	**Time Period**	**Rationale**	**Tools/Techniques**
Assess species abundance, distribution and behavior for migratory birds species providing a baseline on their movements and pathways.	Regional, Local	Pre- and Post-construction/ Operation	The South Atlantic is known to be an important part of the Atlantic Flyway, migratory birds (e.g., Common Terns, Royal Terns, Sooty Shearwaters, American Golden Plovers, Bicknell's Thrushes, Bobolinks, several species of Sandpipers, Whimbrels, Short-Billed Dowitchers, Dunlins, Willets, Semipalmated Plovers, and Red Knots) and additional monitoring is needed to better understand their abundance, distribution, and behaviors. These are not well captured for the South Atlantic and models have been developed with limited sightings data.	Tracking studies (e.g., automated radio telemetry nanotags, GPS satellite tags, geolocators and altimeters) Radar surveys to detect attraction to turbines MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial surveys

Priority Topics	**Scale**[77]	**Time Period**	**Rationale**	**Tools/Techniques**
Targeted monitoring for beach nesting birds during their breeding season to include baselines of movement, foraging habitat, and distribution to provide the ability to measure potential shifts in these factors. As well as bird displacement and barrier effects.	Local, Regional	Pre- and Post-construction/ operation	Beach nesting birds, (e.g. Piping Plover, American Oystercatcher, Wilson's Black Skimmer, Least Tern, Red Knot) breed and forage along these shorelines and travel over water for fall and spring migration. Turbines offshore may negatively impact energy budgets during commuting and migration, and limit access to foraging habitat, potentially resulting in population-level effects.	Tracking studies (e.g., automated radio telemetry nanotags, GPS satellite tags, geolocators and altimeters) Radar surveys to detect attraction to turbines MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial surveys

II. Gulf of Mexico (Texas, Louisiana, Mississippi, Alabama, Florida)

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The Gulf of Mexico, a marginal sea of the Atlantic Ocean, is a highly productive warm-water ecosystem that supports a large diversity of organisms, such as cetaceans, sea turtles, birds, fish, and coral reef (Spies, et al. 2016). The Gulf can be divided oceanographically into eastern and western halves. The eastern half is influenced by clear, Caribbean inflow, and the western half is influenced by the sediment-laden water from the Mississippi River (Hopkins-Murphy et al. 2003). This Gulf system has been heavily altered by human activities, including oil and gas exploration and production and related infrastructure, oil spills, loss of coastal wetlands, heavy fishing pressure, and the loading of pesticides and nutrients, the latter of which contributes to the development of seasonal hypoxia in bottom waters on the Louisiana-Texas continental shelf (Priest, 2005; Dahl, 2011; Sammarco et al. 2013; Spies et al. 2016; Rabalais and Turner, 2019). This hypoxic zone can stretch 15,000 square kilometers or more (Rabalais and Turner, 2019). In addition, natural disturbances driven by hurricanes, river floods, and drought conditions can exacerbate human impacts (Chen et al. 2000). Despite these stressors, the Gulf has moderately high primary productivity, compared to other ocean basins in the world, with the highest productivity found on the continental shelf and in the surface waters (Rabalais, 1990; Spies et al. 2016).

High shelf productivity, resulting from high inputs of terrestrial nutrients, supports Gulf of Mexico fisheries. A number of ESA listed threatened fish species are found in the Gulf, such as smalltooth sawfish and Nassau grouper whose habitat is located off the west coast of Florida, and Gulf sturgeon which uses habitat in the river, estuarine, and shallow nearshore areas along the coast from Louisiana, east of the Mississippi River, to Florida (Gulf of Mexico Fishery Management Council, 2016; NOAA, 2022). The Gulf is also one of the two main regions where Atlantic bluefin tuna are known to spawn. The western population of this highly migratory species, in decline due to overexploitation, spawn in the Gulf from February to June and typically leave by the end of June for feeding grounds in the North Atlantic (Block et al. 2005). One area of important essential fish habitats in the Gulf is the Flower Garden Banks National Marine Sanctuary. First designated in 1992 and expanded in 1996 and again in 2021, this sanctuary protects 17 reefs and banks along the edge of the continental shelf in the northwestern Gulf which include shallow water coral reefs, deeper mesophotic reefs, and algal-sponge communities (Office of National Marine Sanctuaries, 2020).

Twenty-eight different cetacean species are typically found to inhabit the Gulf of Mexico. Among these species are the sperm whale, which is listed under the ESA as endangered, and the Rice's whale (formerly considered a subspecies of the Bryde's whale) which is listed as endangered under the ESA and as critically endangered by the IUCN. The Rice's whale is found exclusively within the Gulf of Mexico and has an estimated population size of only 51 individuals. A five-year study found that Rice's whale prey species, and the oceanographic conditions necessary to support those prey species, also occur between the 100 and 400 m isobaths in the central and western Gulf (NOAA, 2022), and Rice's whales are also regularly acoustically detected within that area (Soldevilla et al. 2022). These multiple lines of evidence indicate that the stretch of water between the 100 and 400 m isobaths represents important habitat for these whales across the entire northern Gulf (NOAA, 2021; NOAA, 2022). The western Gulf is also inhabited by continental shelf and western coastal stocks of bottlenose dolphins, and several bay, sound, estuary stocks of bottlenose dolphins that have small ranges and population sizes meaning they have higher relative vulnerability to impacts (NOAA, 2016; NOAA, 2019). The stock of sperm whales in the Gulf is distinct from other Atlantic stocks and there are estimated to be 1,180 individuals (Jochens et al. 2008; NOAA, 2021). This population typically inhabits the continental shelf and oceanic waters throughout the Gulf, but have often been observed between the Mississippi and De Soto Canyons (Jochens et al. 2008).

Five of the seven sea turtle species in the world, the green turtle, Kemp's ridley, loggerhead, leatherback and hawksbill, are found in the Gulf of Mexico year-round. These species move between different Gulf ecosystems at different parts of their lifecycle, nesting and hatching on beaches and developing and foraging in nearshore (depths of < 200 m) and offshore waters (Valverde and Holzwart, 2017). The Kemp's ridley turtle is listed under the ESA as endangered and 95% of the world's population nest in the western Gulf of Mexico (Valverde and Holzwart, 2017; NMFS, 2015). The hawksbill and leatherback sea turtles are listed as endangered throughout their range, and the loggerhead and the North Atlantic populations of green sea turtles are listed as threatened (Conant et al. 2009; Seminoff et al. 2015; NMFS, 2020).

Diverse and abundant populations of birds use and pass through the Gulf of Mexico due to its varied habitats, warm coastal waters, and its location along the Central, Mississippi, and Atlantic Flyways, the pathways between breeding and wintering grounds for Nearctic-Neotropical migrants moving between the northern U.S. and Canada and Central and South America. The Gulf Coast of the U.S. supports nearly half of the migrating birds in North America, including Piping Plover and Red Knot which are both listed as threatened under the ESA and the Black-Capped Petrel which is identified as endangered by the IUCN. In addition, the Gulf's beaches and barrier islands provide critical habitat to a variety of species that are already subject to a variety of natural and anthropogenic stressors, such as Brown Pelican, Black Skimmer, American Oystercatcher, Snowy Plover, Reddish Egret, and Roseate Spoonbill (Horton et al. 2019).

The Gulf of Mexico is in the early stages of offshore wind development. Wind energy areas have been identified, but with leases yet to be awarded. Monitoring is underway through the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) program and monitoring efforts related to the Deepwater Horizon Oil Spill, but the current survey frequency and intensity through these efforts may be insufficient to capture annual and seasonal changes exhibited by many Gulf species.[78] The below recommendations identify several monitoring priorities for the region's species and habitats.

[78] https://www.boem.gov/gommapps/.

Table 6. Monitoring priorities for the Gulf of Mexico

Priority Topic	Scale[79]	Time Period	Rationale	Tools/Techniques
Flower Banks National Marine Sanctuary and potential expansion areas	Existing area as well as areas proposed under Alternative 4	Pre-, During, and Post-construction /Operation	Unique habitat features such as underwater mountains, ridges, troughs, and hard bottom patches create a chain of protected habitats for ecologically and economically important species. Many of these features were protected as part of a 2021 Sanctuary Expansion but areas considered but not included in the final expansion should also be addressed by BOEM.	Benthic transects and sampling, water column net sampling Visual surveys using ROV/AUV Benthic characterization surveys and mapping to correlate species and habitat health Sonar, side-scan sonar
Rice's whale foraging and habitat use	Gulf of Mexico	Pre-, During-, and Post-construction /Operation	Understand location and extent of Rice's whale foraging areas to understand if/ how they overlap with wind development areas and to detect any potential change in habitat use/ foraging during and post-construction.	Visual surveys (aerial, vessel-based) Passive acoustic monitoring Environmental sampling, including prey sampling, to inform distribution and movement models
Sperm whale foraging and habitat use	Regional	Pre-, During, and Post-construction	Studies of location and extent of sperm whale foraging areas to understand if/ how they overlap with wind development areas and to detect any potential	Visual surveys (aerial, vessel-based) Passive acoustic monitoring

[79] Regions are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = Gulf of Mexico. To differentiate impacts of offshore wind from impacts from climate change or other factors.

Priority Topic	Scale[79]	Time Period	Rationale	Tools/Techniques
			change in habitat use/ behavior.	
Impact of construction and cable-laying on Bottlenose dolphins	Local	Pre-, During, and Post-construction	Assessment and study of the the overlap and potential impact of turbine construction and cable-laying on bottlenose dolphins stocks in wind development areas, including onshore connection areas during and post-construction.[80]	Visual surveys (aerial, vessel-based) Passive acoustic monitoring
Kemp's ridley sea turtle nesting and habitat use	Regional	Pre-. During-, and Post-construction	Studies to understand and determine if/ how wind development areas, wind-related vessel traffic, and onshore connection points impact location and distribution of sea turtles (in-water) and nesting locations and to detect any potential change in habitat use or behavior.	Acoustic telemetry of wild caught and rehabilitated sea turtles Satellite telemetry Aerial surveys (visual, digital)
Assessment of Nearctic-Neotropical migratory birds	Gulf of Mexico	Pre-, During, and Post-construction /Operation	Prepare Vulnerability Analysis that ranks species and species groups vulnerability to collision, displacement and population level impacts on species of birds in Gulf based on their flight behaviors etc. following same studies by BOEM in Atlantic and Pacific.	Automated radio telemetry nanotags (occurrence, flight height, direction) Marine radar (magnitude (i.e., flux), timing, altitude) Acoustic monitoring of flight calls (for birds with sufficient vocalizations)

[80] The small ranges and population sizes of the bottlenose dolphin stocks in the Gulf create a higher relative vulnerability to impacts (NOAA, 2016; NOAA, 2019).

Priority Topic	Scale[79]	Time Period	Rationale	Tools/Techniques
			Understand factors (e.g., weather) that drive variation in migratory altitude. Test methods that reduce collision probability (lighting, tower design and spacing, etc.). Evaluate real-time monitoring protocols (e.g., radar).	
Pelagic seabirds (e.g., Black-capped Petrel, Audubon's Shearwater, etc.)	Gulf of Mexico	Pre-, During, and Post-construction /Operation	Baseline data needed to understand distributions, migratory pathways, and flight behavior of seabirds. Research needed to determine wehther turbine platforms mimic upwelling ocean turbulence foraging cues.	Avian tracking studies, including automated radio telemetry nanotags and receivers, GPS satellite tags, geolocators and altimeters, as appropriate for the species of concern Radar surveys to detect attraction to turbines MOTUS telemetry receiving stations in coastal/island locations and on installed turbines Digital aerial and vessel surveys as appropriate

III. Pacific

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The California Current Ecosystem (CCE) extends along the West Coast of North America from Baja California, Mexico, to British Columbia, Canada. This unique, complex marine ecosystem is a highly productive area of global significance as one of the four major Eastern Boundary currents found in Earth's oceans (Marsh and van Sebille 2021). The CCE is remarkably dynamic, with high interannual, seasonal, and even daily variability, which influences the distribution and presence of many marine species and creates hotspots of primary productivity (Jacox et al. 2015, Mannocci et al. 2017, Pauly and Christensen 1995). This variability is a result of the input of cool, nutrient-rich water in wind-driven seasonal upwelling, and by nutrient output from large river systems along the West Coast (U.S. Carbon Cycle Program, 2008). Generally, the CCE experiences stronger upwelling in the spring and summer, which forms the base of the coastal and ocean food web off the West Coast (Bograd et al. 2009, Deutsch et al. 2021, Garcia-Reyes and Largier 2010). The ecosystem supports important fisheries, recreation, and other activities for tens of millions of people living along the West Coast.

The continental shelf and shelf break are important foraging areas as well as migratory corridors for marine mammals, marine birds, turtles, and fish. Nearshore and coastal ecosystems include kelp forests, eelgrass beds, estuaries, tidal marshes and floodplains, and tide pools. Important offshore habitat includes offshore islands, rocky reefs, seastacks, seamounts, and submarine canyons. Many species use different habitats in various life stages, such as shorebird and waterbird species seasonally inhabiting nearshore areas and using offshore migration corridors.

The CCE is highly susceptible to and influenced by shifts in temperature and ocean currents, particularly the large interannual variability driven by ocean basin-scale processes: the El Nino-Southern Oscillation, Pacific Decadal Oscillation, and the North Pacific Gyre Oscillation (Di Lorenzo et al. 2013, NOAA CCIEA 2022). The effects of rising global temperatures on coastal upwelling systems like the CCE are complex, and impacts are hard to predict and variable in different regions of the CCE (King et al. 2011, Weber et al. 2021, Xiu et al. 2018).[81]

[81] The Marine Heat Wave of 2014-2016 is a recent example, which constricted upwelling to a narrow band along the shore, resulting in a range of impacts on effected species. See: Cavole et al. 2016, Fleming et al. 2016, Ingman et al. 2021, Jones et al. 2018, Santora et al. 2020.

Along with impacts from climate change, such as increased sea surface temperature and ocean acidification,[82] threats to the CCE in California, Oregon, and Washington include pollution,[83] habitat loss, and harmful algal blooms (HABs). Warming temperatures may alter coastwide species' distributions and community composition, with warm-water species moving north into previously unoccupied areas.

The recommendations identified for California and the Pacific Northwest regions reflect priorities for a large, interconnected ecosystem spanning the West Coast of the U.S. In addition to monitoring for impacts directly stemming from the development of offshore wind, we urge state and federal agencies to incorporate monitoring for individual health and overall population status of vulnerable species; changes may increase susceptibility to the effects of offshore wind and indicate a need for additional mitigation measures. As described above, the CCE is a highly biodiverse and productive ecosystem, supporting foraging grounds and migratory corridors for many species. The long-term health of the ecosystem should be monitored to understand the role of offshore wind development in cumulative impacts, including from climate change.[84] Establishing baseline health indicators for at-risk and indicator species and monitoring changes through phases of offshore wind development can enable detection of responses to systemic habitat changes.[85]

a. California

California has prioritized coastal and marine conservation issues as a core value, reflected in strong state environmental laws and policies.[86] There are currently 109 federally recognized Tribes and many more non-federally recognized Tribes in California. Tribes hold land throughout the state, and, although only the Yurok Reservation includes coastal areas,[87] the coast also includes sacred Indigenous sites, both on and offshore, important to the practices and wellbeing of many Indigenous communities. The CCE hosts an abundance of commercial uses, including shipping, fishing, aquaculture, oil and gas development, as well as Department of Defense activities; recreational opportunities include surfing, fishing, whale watching, boating, diving; and others.

[82] The Newport Hydrographic Line, a multi-decade dataset tracking physical, chemical, and biological oceanographic metrics off Newport, Oregon, provides information on ocean-climate and ecosystem structures: https://www.integratedecosystemassessment.noaa.gov/regions/california-current/newport-hydrographic-line

[83] Pollution includes legacy contaminants still present in the CCE despite bans enacted in the 1970s (DDT, PCBs) and nutrient pollution driven by agricultural runoff, which can drive hypoxia in the nearshore environment.

[84] Environmental monitoring, e.g., for harmful algal blooms or other toxins, can also indicate additional stressors that may influence cumulative impacts to at-risk species.

[85] Health monitoring may also detect harm, serious injury, or mortality directly caused by development activities (e.g., vessel strike). This monitoring may include tagging to monitor behavioral changes, biological sampling (necropsies, fecal and breath sampling, DNA sampling, aerial photogrammetry (e.g., Burnett et al. 2018), and stranding data), and beach monitoring for bird carcasses near colony and nesting areas. See NMFS Stranding Response Program and California/USFWS stranding; Coastal Observation and Seabird Survey Team. Specific necropsy standards for dead stranded animals collected in OSW areas should be developed.

[86] E.g., the California Coastal Act of 1976 (California Public Resources Code § 30000–30900), the Marine Life Protection Act (California Fish and Game Code § 2850–2863), and the California Coastal Sanctuary Act of 1994 (California Public Resources Code § 6240–6245).

[87] California Tribal Communities.

Protected areas include a network of 124 state-designated marine protected areas (MPAs) in addition to the federally designated Cordell Bank, Greater Farallones, Monterey Bay, and Channel Islands National Marine Sanctuaries.[88] California has a vast network of state parks and numerous National Parks, Monuments, and Recreation Areas that include coastal areas.[89] Many of the 44 National Wildlife Refuges in California include coastal and estuarine areas.[90]
Important bathymetric features can be found in Northern, Central, and Southern California ocean waters, including 63 seamounts (e.g., Davidson Seamount), submarine canyons including Monterey Canyon (the deepest submarine canyon on the West Coast),[91] offshore rocky reefs, and a significant amount of continental slope habitat.[92] Submarine canyons are often associated with trophic hotspots and highly productive areas (Santora et al. 2017, Santora et al. 2018). Eddies affect local environmental conditions and transport upwelled water (Chenillat et al. 2018).[93]

In waters off California, there are 173 special status species listed by the state[94] and/or federal government as threatened or endangered, including multiple fish, seabird, sea turtle, and marine mammal species, as well as two marine invertebrates.[95] California designates certain species that are rare, vulnerable, or in need of additional protection as "Fully Protected" under state law: this list includes fish, marine birds, and marine mammals.[96]

Continental slope habitat supports infaunal and microbial communities that play an important role in nutrient cycling and CO_2 exchange (Thurber et al. 2014). Waters off California are largely unmapped at a resolution or scale needed to provide comprehensive biological characterization of benthic communities; however, there are some known areas and features that warrant protection from human development, such as hard bottom habitat and corals. Habitat-forming macroinvertebrates (e.g., sponges and corals) in areas that generally have minimal rugosity provide biogenic structures that are associated with high fish density and diversity and are important for commercial species like deep-living rockfishes and thornyhead (Buhl-Mortensen et al. 2010).

Hundreds of fish species inhabit the CCE, including highly migratory species (HMS), coastal pelagic species (CPS), over 100 species of rockfish, and more than 90 species of groundfish. Many of these fish have decreasing populations and have been identified as near threatened, vulnerable, or endangered by

88 California MPA Network; The Chumash Heritage National Marine Sanctuary has been proposed and is under review by NOAA as of December 2022.
89 California state parks map; National Park Service: California.
90 USFWS: California National Wildlife Refuges.
91 Monterey Bay Aquarium Research Institute: Monterey Canyon.
92 Seamounts and oceanic ridges are especially prevalent in Southern California: California Offshore Wind Energy Gateway.
93 The Southern California Current Ecosystem is notably characterized by eddies around the Channel Islands.
94 California Department of Fish and Wildlife.
95 Black abalone and white abalone are listed under the federal ESA: NMFS Species Directory: Threatened and Endangered, Corals and Invertebrates.
96 CDFW Fully Protected Animals.

the International Union for Conservation of Nature (IUCN);[97] several species are also listed under the state and/or federal Endangered Species Act (ESA).[98]

Commercial and recreational fisheries are managed by state and/or federal agencies.[99] Select species have Fishery Management Plans (FMPs) under the Pacific Fisheries Management Council (PFMC), developed with multiple states for EEZ waters.[100] Tribes co-manage specific fisheries with the state and PFMC, and the Yurok and Hoopa Valley Tribes have a federally reserved right to harvest Klamath River fish.[101] The PFMC designates Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) for managed species: groundfish, CPS, and HMS have EFH in ocean waters off California, salmon do not have EFH in ocean waters.[102] EFH for CPS and HMS is derived from distributional and oceanographic data and may vary between years, depending on data such as sea surface temperature. Benthic fish species are more closely tied to fixed habitat structures (Roberts et al. 2020). Green sturgeon and the southern Distinct Population Segment (DPS) of eulachon have federally designated critical habitat.[103] HAPCs and EFH have varying regulations that prohibit certain types of fishing in some areas (e.g., HAPCs).

Four species of sea turtle use California ocean waters. All are listed under the federal ESA, and leatherback sea turtles are a candidate for an endangered listing under the California ESA. Critical habitat has been designated for leatherback sea turtles,[104] which forage in the CCE off California August to November (Benson et al. 2011).[105] The presence of juvenile loggerhead sea turtles in California waters largely has been limited to offshore areas in southern California and Baja; Olive Ridley habitat includes Southern California, but they have been found stranded on beaches as far north as Oregon.[106] Ocean warming and climate change impacts likely affect the migratory and foraging behavior of sea turtles.

A minimum of 33 cetacean species use the CCE off California. Multiple species and populations are listed under the federal ESA.[107] The Southern Resident killer whale Distinct Population Segment (DPS) and two DPSs of humpback whales have federally designated critical habitat off California.[108] Foraging and migration Biologically Important Areas (BIAs) have been identified for blue whales, humpback whales,

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[97] IUCN Redlist: Near threatened species include Pacific bluefin tuna and blue shark; vulnerable species include common thresher, bigeye thresher, and bigeye tuna; the pelagic thresher is endangered.
[98] Notably, Delta smelt and several salmon populations are on both the California and Federal endangered species lists. California Threatened and Endangered Species.
[99] Plans for state-managed fisheries are described under the California Marine Life Management Act.
[100] The PFMC manages salmon, groundfish, coastal pelagic species, and highly migratory species.
[101] Tribes - Pacific Fishery Management Council.
[102] For detailed locations, see NOAA Fisheries Essential Fish Habitat mapping tool.
[103] Green Sturgeon Southern DPS critical habitat from Monterey Bay, CA to the CA/OR border; Southern Eulachon DPS critical habitat includes estuaries in northern California.
[104] Leatherback sea turtle critical habitat.
[105] When SST is warmest, suggesting that leatherback foraging is driven by ocean conditions.
[106] Oregon Marine Mammal Stranding Network records.
[107] NMFS Threatened and Endangered Species Directory.
[108] 86 FR 41668: Revision of Critical Habitat for the Southern Resident Killer Whale Distinct Population Segment (through Point Sur, CA); 86 FR 21082: Designating Critical Habitat for the Central America, Mexico, and Western North Pacific Distinct Population Segments of Humpback Whales.

and gray whales;[109] small and resident BIAs for local populations of harbor porpoises (Calambokidis et al. 2015).[110] The extent of habitat use by rare or data deficient species including beaked whales, sei whales, and sperm whales is poorly understood. Small cetaceans may be present in California ocean waters year-round, using both coastal and offshore areas for foraging, travel, socialization, and reproduction.[111] More information on stock structure is needed for many species;[112] more robust baseline distribution and abundance data is needed for all cetaceans, especially in offshore areas seaward of the continental shelf and in the winter and early spring.

Six species of pinnipeds use California ocean waters; Steller sea lions occur as far south as Central California.[113] All six species have identified haulout and rookery sites on the California coast or offshore islands, particularly the Farallon and Channel Island archipelagos. Guadalupe fur seals are listed under the federal ESA.[114] Elephant seals and fur seals migrate through and forage in pelagic areas, including the continental shelf (Adachi et al. 2021). California sea lions rely on diverse prey resources found in areas of upwelling.[115] California is also home to the Southern sea otter, listed as threatened under the federal ESA and as a fully protected mammal under California law. Sea otters are now restricted to a fraction of their historical range, primarily California's Central Coast.

More than 180 species of marine birds can be found off California, comprising millions of individuals. Seven seabird species are listed under the federal and/or state ESAs.[116] Important Bird Areas (IBAs) have been described in offshore and coastal waters and throughout the state.[117] Distribution is broadly divided into coastal, continental shelf, and offshore regions, and many species use multiple areas depending on the season and activity (migrating, foraging, or nesting). California's offshore islands host large numbers of breeding seabirds during the spring and summer, while beaches and protected coastal waters provide overwintering habitat to shorebirds, waterbirds, and waterfowl that migrate in from more northerly breeding grounds. Notably, the range of the ashy storm-petrel is entirely within the CCE. This endemic species nests exclusively on islands off California and northern Mexico, with the largest

[109] The Pacific Coast Feeding Group of gray whales also seasonally forage in Northern California (Calambokidis, J., Laake, J. and Perez, A. 2019); the Eastern DPS of gray whales is currently experiencing an Unusual Mortality Event.

[110] Map of cetacean Biologically Important Areas. BIAs are currently being updated by NMFS. BIAs do not capture all foraging hotspots, and foraging opportunities and habitat use are influenced by ocean conditions and upwelling plumes. Changing ocean conditions may increase uncertainty in seasonal distribution and abundance (Fleming et al. 2016, Ingman et al. 2021, Santora et al. 2020).

[111] More information on the influence of ocean conditions on the distribution of small cetacean species is needed; at least some tropical and warm-temperate species may change distribution patterns with warming ocean temperatures in the CCE (Becker et al. 2018).

[112] There are three Distinct Population Segments of humpback whale in the CCE, with further separation into Demographically Independent Populations pending. Three small cetacean species in the CCE (orcas, harbor porpoises, and bottlenose dolphins) are divided into separate stocks with different home ranges. More species likely have distinct stocks that have not been designated yet.

[113] NOAA Species Directory.

[114] Guadalupe fur seals recently experienced an Unusual Mortality Event linked to malnutrition caused by changing ecological conditions.

[115] A recent UME for California sea lions was attributed to ecologically driven prey shifts, linked to the 2013-2015 marine heatwave (Lowry et al. 2022).

[116] Short-tailed Albatross, California Brown Pelican, Western Snowy Plover, California Least Tern, Marbled Murrelet, Scripp's Murrelet, and Guadalupe Murrelet: California Threatened and Endangered Species.

[117] Audubon Important Bird Areas.

breeding colony on California's Farallon Islands, and most of the world's population is found in Monterey Bay in the fall (Ford et al. 2021).

There are 25 species of bats in California coastal areas. Bat presence and use of offshore areas is not well known. Hoary bats likely migrate along the Pacific Coast and are found on offshore islands (Southeast Farallon Island); other species are found in the Channel Islands, suggesting some movement to offshore areas (Brown and Rainey 2018, Solick and Newman 2021). The Western Bat Working Group notes species of high conservation concern.[118]

Due to California's narrow and deep continental shelf and slope, floating offshore wind is the most likely type of offshore wind to be developed. In 2016, BOEM began engagement in offshore wind planning in California waters because of an unsolicited lease request to develop an area off Morro Bay. Two Wind Energy Areas have been designated in federal waters off California: off Humboldt Bay in Northern California and off Morro Bay on the Central Coast. BOEM completed a Final Environmental Assessment (EA) for both. The Final Sale Notice for both federal WEAs was published October 18, 2022, with the lease sale occurring December 6, 2022. Two projects in state waters are under consideration by the California State Lands Commission. California is currently developing a strategic plan for offshore wind development in federal waters, including a permitting roadmap, transmission and port assessments, siting analysis for future projects, and an economic assessment.

Table 7. Monitoring priorities for California[119]

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
Comprehensive mapping of benthic habitat, especially important habitat areas for fish (e.g., HAPC)	Local, Sub-regional	Pre, During, Post-construction /Operation	Detailed benthic habitat surveys are needed pre-construction in offshore wind sites to identify biogenic habitats, classify important areas, and characterize areas of likely high ecological importance (e.g., HAPC, rocky reef habitat) in the CCE.	Geophysical surveys with sonar and multibeam ROV and AUV surveys Drop cameras Seabed sampling to identify bottom type and species present
Altered aerodynamics, hydrodynamics, and associated ecosystem impacts	Local, Sub-regional, Regional	Pre-, Post-construction /Operation	Wind-driven upwelling supports the primary productivity that is the base of the high biodiversity in the CCE.	In situ measurements of aerodynamics and turbine wake; in situ measurements of hydrodynamics

[118] Species Matrix – Western Bat Working Group.
[119] Regions are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = CCE. To differentiate impacts of offshore wind from impacts from climate change or other factors.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			Individual turbines and multiple wind energy developments in the CCE (including floating wind infrastructure) may cause localized[120] and cumulative changes in wind and upwelling patterns (e.g., wake effects, altered stratification and mixing), with broader ecosystem impacts[121] (changes to nutrient delivery, primary productivity, distribution and concentration of key prey species, habitat use by higher-trophic-level species).	Aerodynamic and hydrodynamic models Plankton and prey sampling (forage fish) Physical and coupled biogeochemical models to assess changes in wind stress and upwelling[122]
Distribution and habitat use of fish: Highly Migratory Species (HMS), Coastal Pelagic Species (CPS), and salmon	Local, Sub-regional, Regional	Pre-, During, Post-construction /Operation	Broad CPS and HMS distribution and habitat use depends on oceanographic conditions (temperature, productivity) and is variable on short, seasonal, and annual timescales.[123] Areas currently considered "low" or "high" abundance and EFH may change with ocean conditions, impacting the presence and habitat use of these species around	Acoustic backscatter to identify large aggregations of CPS Personned aerial surveys for broad distribution Tagging (satellite, acoustic, biologging) for distribution and behavior characterization Fishery catch data (commercial,

[120] Ryan et al. 2022. Blue whales may track short-duration upwelling events to maximize energy gain.
[121] Including changes to nutrient-driven processes like Harmful Algal Blooms.
[122] Daewel et al. 2022, Raghukumar et al. 2022.
[123] Short timescale changes within one upwelling system can affect fine-scale distribution of some CPS fish, changing distribution between days (Benoit-Bird, Waluk, and Ryan 2019).

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			infrastructure. Spatial density modeling can help inform changes in CPS and HMS abundance and presence and is needed to monitor EFH for these species. More information is needed on the oceanic distribution and habitat use of different species and stocks of salmon to assess overlap with development areas and monitor impacts on salmon. Addition of floating OSW infrastructure to pelagic areas may act as fish aggregating devices, which may change distribution and/or catchability of these fish or displace them from preferred habitat areas.	recreational, Tribal) and vessel surveys and sampling (net tows and trawling) can inform oceanic distribution and changes to distribution
Electromagnetic field (EMF) effects on species that detect bioelectric and magnetic fields, including elasmobranchs, Dungeness crabs, salmon, sturgeon, and sea turtles	Local, Sub-regional	Pre-construction (lab); Post-construction /operation (field)	Baseline data is needed for these key CCE species to determine sensory thresholds and response to EMF fields, movement patterns, identify foraging areas and important habitats, monitor use by seasonal species, and determine migration paths.	Lab and field studies with video recording and biologging tags Direct measurements of EMF emitted from project-associated infrastructure, including turbines, inter-array cables, and transmission lines

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			Lab-based studies will help develop standardized parameters and baseline species behaviors.[124]	
Baseline abundance and distribution for large whales, including for less well-understood species (sei whales, sperm whales, beaked whales, and North Pacific right whales), and including fine-scale habitat use for ESA-listed humpback, fin, and blue whales, and gray whales[125]	Local, Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Improved identification of locations of different (and potential) foraging areas, changing patterns of use, and environmental drivers of habitat use is needed to assess overlap with wind development areas and vessel traffic routes, and to monitor for displacement. More comprehensive monitoring and research efforts are needed to fill data gaps to inform baseline year-round occurrence of ESA-listed large whales and gray whales, including their presence and use of different habitat areas (coastal, continental slope, offshore), with a	Visual surveys (digital and personned aerial; vessel-based)[127] and infrared monitoring (vessel-based) Opportunistic sighting data[128] Tagging (satellite telemetry, biologging tags, accelerometer suction cup tags) to track broad and fine-scale habitat use and categorize behaviors Passive acoustic monitoring (archival, real-time)[129] Focal follows to assess changes in habitat use Photo-ID and DNA sampling to detect differences in

[124] Oregon State University recently received funding to conduct "non-invasive laboratory-based behavioral experiments in Longnose skate and Dungeness crab to quantify their minimum sensory thresholds, detection ranges, and behavioral responses to EMFs from HVCs." Biennial Projects 2022-2024.
[125] Eastern North Pacific gray whales are under an ongoing Unusual Mortality Event.
[127] Incorporate and augment the CDFW RAMP surveys on large whale presence, abundance, and distribution: The CDFW Risk Assessment and Management Program (RAMP) monitors overlap of protected humpback and blue whales and leatherback sea turtles during the Dungeness crab fishing season; currently, risk assessments are conducted monthly starting in November through the end of the fishing season. By year 5 of the program, aerial surveys will occur monthly October-December and March-June.
[128] From whale watch reports, citizen science programs.
[129] From autonomous vehicles, profile drifters, or moored surface buoy systems.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			consideration for seasonal presences.[126] For vulnerable, poorly observed large whales with little information currently available, migration corridors, foraging areas, and environmental drivers of habitat use need to be identified to enable understanding of potential impacts from development.	abundance and distribution of distinct populations Environmental sampling Spatial density models, predictive habitat models to understand distribution and habitat suitability
Abundance and distribution of small cetaceans, particularly discrete populations of harbor porpoises, and CCE stocks of bottlenose dolphin, Risso's dolphin, and Dall's porpoise[130]	Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Small cetacean population structure and abundance is not well known for most species, and there are spatial (offshore) and temporal (winter/spring) data gaps. More information is needed on environmental drivers of presence, distribution, and habitat use to assess when and where small cetaceans may occur in potential wind areas.[131]	Visual surveys (personned and digital aerial, vessel-based) and infrared monitoring (vessel-based) and opportunistic sightings data Tagging (satellite, biologging) for broad habitat distribution and to categorize behaviors

[126] Models such as the California Current Integrated Ecosystem Assessment incorporate environmental, biological, economic, and social indicators and assess short-term trends and long-term means. Current models include data from July-November; additional data is needed for winter-spring (December-June), particularly for the spring return from low latitude breeding areas, when foraging success is critical to nutrient intake. Fin whales have shown high residency to localized areas, and movement from shelf waters in the winter to offshore waters in the summer and have been observed overwintering off the California coast (Scales et al. 2017).

[130] These species have identified CCE stocks; Dall's porpoise may be able to represent small cetaceans generally for life history and ecological function in ecological models (e.g., Washington Dept. of Fish and Wildlife Marine Spatial Plan).

[131] In addition, warm-temperate species not commonly present in the northern CCE may experience northward range shifts in response to warming ocean temperatures – their presence and habitat use should also be noted (e.g. false killer whales, striped dolphins, rough-toothed dolphins).

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			Discrete populations with limited ranges may be especially vulnerable to development in their habitat. More wide-ranging species that use offshore waters throughout the CCE may experience higher cumulative impacts from coastwide development.	Passive acoustic monitoring (archival, real-time) Photo identification to track individuals in distinct populations Spatial density models, predictive habitat models to understand distribution and habitat suitability
Distribution and fine-scale habitat use of pinnipeds	Local, Sub-regional, Regional[132]	Pre-, During, and Post-construction /Operation	Development may cause impacts from noise and disturbance, vessel traffic risk, changes in foraging behavior, and potential hearing threshold shifts in pinnipeds. Monitoring of presence and habitat use, especially haulout and rookery areas both nearshore and offshore, along with environmental drivers of habitat use and species health could help assess impacts. More information is needed on offshore habitat use and migration routes for fur seals and Northern elephant seals.	Personned and digital aerial surveys for large-scale population counts and distribution Shore-based surveys for haulout and rookery locations and nearshore habitat use[133] Tagging (satellite, radio, biologging) to track movements of individuals and categorize behaviors Spatial density models, predictive habitat models

[132] Regional monitoring is necessary for wide-ranging offshore species of pinnipeds.
[133] Including opportunistic sightings data.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
Baseline distribution and habitat use of sea turtles	Local, Sub-regional, Regional	Pre-, During, and Post-construction /Operation	A more complete picture of sea turtle occurrence and habitat use in the CCE is needed to understand impacts from development.	Visual surveys (personned and digital aerial, vessel-based) Tagging (satellite, radio, acoustic, biologging, camera tags) to track movement, dive patterns, surface time, and categorize behaviors Data from opportunistic sightings and fishery observers Spatial density models, predictive habitat models
Establish localized baselines for southern sea otter population density and distribution Environmental monitoring in sea otter habitat	Local, Sub-regional	Pre-, During, and Post-construction /Operation	Establishing local baselines of sea otter density, distribution, and habitat use in areas where otters and potential offshore wind areas overlap will be essential to assess potential impacts from development, including transmission cable routes.[134] Localized changes can be compared to range-wide	Personned aerial surveys for range-wide census and offshore areas; shore-based surveys for other areas Radio telemetry Physical and biogeochemical models to assess oceanographic changes in or near wind development

[134] Coastal activities of OSW development with greatest potential to affect otters include vessel traffic, transmission line siting and construction, and nearshore operations.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			census data to assess impacts	areas, including transmission cable routes
Abundance, distribution, habitat use patterns, and oceanographic drivers for seabird, waterbird, shorebird, and landbird species with limited information currently available, particularly threatened and endangered species[135] Identify individual risk factors and overall species vulnerability to collision and displacement,[136] and assess the potential for changes under a range of likely oceanographic conditions that may affect distribution of	Local, Sub-regional, Regional	Pre-, During, and Post-construction	There are spatial and temporal data gaps on distribution and abundance across seasons and years, particularly related to offshore foraging areas and migration patterns/routes. In particular, more data is needed on the offshore habitat use of species that are small-bodied, rare, declining, or forage nocturnally.[138] Oceanographic and forage fish data can be used to assess the influence on marine bird distribution and assess changes. Information on habitat use is important for species that may be more vulnerable to collision or displacement. Additional data is needed	Visual surveys (personned and digital aerial, vessel-based) Infrared monitoring (aerial) for nocturnal detection Tagging (satellite, MOTUS,[140] automated nanotags, GPS, geolocators) provides information on occurrence, flight height and direction, and macro-scale displacement Marine radar to assess flight altitude, timing, and flux Acoustic receivers detect vocalizing birds

[135] Federally listed species and additional taxa that have been identified as species of conservation concern (USFWS 2021) will require particular attention. In the CCE, albatrosses are at varying stages of recovery and their high flights may make them especially vulnerable to collision. Furthermore, because Europe's offshore wind farms encompass marine habitats with few or no procellariiform seabirds present, we have no comparable studies even for making general inferences about the collision risks from offshore wind farms for the shearwaters, gadfly petrels, and other tubenoses that are common in the CCE.
[136] "Central place" foragers including Leach's and fork-tailed storm petrels may be displaced or impacted by development occurring between breeding islands and offshore foraging areas.
[138] Ashy storm petrels, alcids and albatrosses with nocturnal foraging habits have increased collision vulnerability; in the breeding season populations congregate on offshore islands and foraging movements are more restricted.
[140] MOTUS stations can be positioned on coastal and island locations off the West Coast, as well as on turbines.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
seabirds and their prey, as well as transitory species (such as the Red Knot[137])			on behavior (e.g., flight height and strategy, time spent in rotor-swept zone)[139] and population status to update vulnerability rankings and assess risk. Identifying high density areas can support the development of buffer zones. The potential impacts to transitory species are unknown but may be significant.	Spatial distribution and predictive density models[141] Risk modeling[142] and energetic modeling
Habitat use patterns and displacement and barrier effects for West Coast alcids (guillemots and murres); grebes, terns, loons, albatross, petrels,[143] and shearwaters; and migrating land birds.	Sub-regional, Regional	Pre- and Post-construction /Operation	Information on habitat use is important for CCE species with high displacement vulnerability due to avoidance rates, and additional pelagic species transiting the area may be subject to displacement.[144] Monitoring local populations and displacement surveys can provide information on	Visual surveys (digital and vessel-based) Tagging (satellite, MOTUS), geolocators and altimeters for avian tracking studies Marine radar to assess flight altitude, timing, and flux

[137] Species with the highest collision vulnerability spend high percentages of time flying at the height of wind turbine blades (Kelsey et al 2018).; however, the distribution and behavior of species with lower collision vulnerability should be considered in assessing overall risk. For example, seabirds that traverse wind energy areas moving between nesting and foraging areas – changes in distribution or habitat use may impact collision vulnerability.
[139] For example, North Pacific albatrosses have low maneuverability in flight and sleep on the wing, increasing collision vulnerability.
[141] For example, Leirness et al. 2021.
[142] Update USGS/BOEM collision and displacement vulnerability database.
[143] "Central place" foragers including Leach's and fork-tailed storm petrels may be displaced or impacted by development occurring between breeding islands and offshore foraging areas.
[144] Update models in Kelsey et al. 2018.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			potential displacement or barrier effects. Some West Coast species navigate using barometric pressure gradients; the impacts of turbine blades on these navigation aids are unknown and need to be monitored.[145]	Infrasonic soundscape characterization Altimeters and pressure sensors to detect changes in flight heights or dive depths
Marbled Murrelet winter distribution	Regional	Pre-construction	More information is needed about wintering distribution and foraging patterns. In particular, there is a need to identify areas used during the flightless fall molt period.	Radio telemetry Marine radar to track large-scale movements between nesting areas and wintering distribution
Abundance, distribution, and habitat use of offshore and coastal areas by bats Environmental drivers of habitat use	Local, Sub-regional	Pre-construction, Operation	There is no baseline data for what species, habitat use (migration, commute between foraging areas, foraging), activity rates, and movement of bats in offshore and coastal areas of the CCE. Basic information on species and activities is essential to assess the potential impacts of development.	Infrared monitoring (aerial) and acoustic receivers for presence and flight information Tagging (satellite, radio) and marine radar to track large-scale movements between land and offshore areas Prey sampling to assess foraging in offshore areas Environmental data to inform offshore migration conditions

[145] Hagstrum, J.T. 2013; Breuner, C.W. et al. 2013; Schomer, P.D. et al. 2015.

b. Pacific Northwest

The Pacific Northwest (PNW) region includes the northern CCE off Oregon and Washington. The PNW coast has a diversity of habitats ranging from long sandy beaches and dune systems to rugged cliffs and rocky headlands.[146] Drift and erosion change the shape of the shore on a seasonal basis, especially in littoral cells associated with large headlands.[147] Numerous bays and estuaries provide estuarine nutrients that contribute to primary productivity, creating essential habitat areas on the coast for a diversity of species.[148]

Management and regulatory tools for coastal and marine resources vary by state.[149] Natural resource industries have historically driven development in the PNW; in recent decades both states added conservation measures and elevated environmental services as management priorities.[150] Existing uses of the ocean and coastal areas include robust commercial and recreational fishing activities, marine trade and shipping, aquaculture (shellfish, marine plants, salmon hatcheries), tourism and recreation, and military activity.[151]

Tribal nations maintain communities along the coast and co-manage marine resources with state agencies as sovereign nations. Five federally recognized Tribes inhabit coastal areas of Washington State with designated reservation areas; four have treaties with the U.S. that secure access to Usual and Accustomed fishing grounds.[152] Five Tribal Nations live in Oregon's coastal area.[153] Offshore and coastal areas have important archaeological sites, and unidentified sites likely exist underwater due to changes in sea level.

Protected areas in Washington include the Olympic National Marine Sanctuary (offshore) and the Olympic National Park (on land), and an extensive system of state conservation areas including seven marine aquatic reserves, marine preserves, species-specific exclusion zones, and octopus protection areas.[154] Oregon has five marine reserves, nine marine protected areas, one seabird protection area,

[146] Washington Marine Spatial Plan; Oregon Geographic Land Description.
[147] State of Oregon Dept. of Geology and Mineral Industries.
[148] Notable estuaries include Grays Harbor and Willapa Bay in Washington, the transboundary Columbia River estuary, and Nehalem Bay, Tillamook Bay, and the Umpqua River in Oregon.
[149] Oregon: Territorial Sea Plan and Ocean Plan; Geographic Location Description in Ocean Stewardship Area. Washington: Marine Spatial Plan and State Ocean Resource Management Act. Both states have advisory councils on ocean use and planning.
[150] Historically, commercial use of the ocean and marine resources has been the highest priority for both states. The establishment of Oregon's marine reserves began in the mid-2000s.
[151] The entire PNW Coast is included in the U.S. Navy Northwest Training and Testing Range; U.S. Coast Guard training activities occur in the region as well.
[152] The Makah Tribe, Quileute Tribe, Hoh Tribe, and Quinault Indian Nation. The Shoalwater Bay Tribe has a reservation in Willapa Bay but does not have a ratified treaty with the U.S.
[153] Confederated Tribes of Coos, Lower Umpqua, and Siuslaw; Confederated Tribes of Grand Ronde; Confederated Tribes of Siletz Indians; Cow Creek Band of Umpqua Tribe of Indians; and the Coquille Indian Tribe. We note that Oregon Confederations of Tribes contain multiple, diverse Tribes and bands. Treaties between Oregon Tribes and the U.S. were created but not ratified: ratified treaties do not represent the extent of the promises and negotiations made between the U.S. Government and Tribes, nor do federally recognized Tribes represent the only Tribes in an area, therefore Tribal concerns should not be limited only to existing treaties.
[154] Protected areas are in inland waters (the Salish Sea) and coastal areas: WA MPAs.

and multiple marine gardens and research reserves.[155] Both states have a network of National Wildlife Refuges: three offshore (Flattery Rocks, Quillayute Needles, Copalis)[156] and two mainland (Grays Harbor and Willapa) in Washington; three marine (Three Arch, Oregon Islands, and Cape Meares)[157] and three estuarine (Bandon Bay, Nestucca Bay, Siletz Bay) in Oregon.[158]

Offshore waters are highly productive, and though seafloor mapping data is limited for the region (Battista et al. 2017), complex bottom habitats, from sand or mud bottom to rocky reefs and banks to submarine canyons have been identified.[159] The continental shelf break and slope support a broad array of marine species, including benthic coral and sponges, and robust marine resource industries.[160] Notable bathymetric features include the Juan de Fuca ridge and its seamounts and hydrothermal vents, earthquake faults in the Cascadia Subduction Zone,[161] submarine canyons,[162] and offshore rocky banks (Goldfinger et al. 2014). The Juan de Fuca Canyon system is particularly diverse seafloor habitat, with deep-sea communities of long-lived coral and sponges. Hotspots of biodiversity are associated with submarine canyons that channel coastal sediment and nutrients to the seafloor, offshore islands and seastacks that provide important habitat above and below the sea surface, and the Juan de Fuca eddy and Columbia River Plume.[163]

Notable invertebrate species include Dungeness Crab, abalone, market squid and Giant Pacific octopus, sea stars, sea urchins, and scallops. Many of these species are on state lists as species of concern or strategic species;[164] Dungeness crab is the largest single-species commercial fishery in Oregon and a benthic indicator species. Coastal (tide pools, estuaries), open ocean, and benthic habitats are important for invertebrate species.

Hundreds of fish species inhabit the northern CCE, including over 100 species of rockfish and more than 90 species of groundfish. Many have decreasing population levels and have been identified as near threatened, vulnerable, or endangered by the International Union for Conservation of Nature (IUCN)

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[155] Oregon Marine Reserves; Oregon eregulations: Oregon Dept. of Fish and Wildlife. 2022. Marine Reserves Program Synthesis Report: 2009-2021. Oregon Dept. of Fish and Wildlife. Newport, Oregon. Regulations and access vary for marine reserves, MPAs, and marine gardens.
[156] The Washington Maritime National Wildlife Refuge Complex includes 870 rocks, reefs, and islands, and is a wilderness area.
[157] The Oregon NWR complex protects 1,853 rocks, reefs, and islands, and are designated wilderness areas.
[158] All Pacific Northwest NWRs include important habitat for a variety of taxa and have limited or no public access.
[159] Additional studies are underway to identify hazards associated with fault lines (Earthquakes, landslides, and tsunamis: USGS Cascadia Subduction Zone Marine Geohazards.) and to improve information on benthic communities, including deep-sea corals and chemosynthetic communities (Laidig et al. 2021; USGS Expanding Pacific Research and Exploration of Submerged Systems).
[160] Including infaunal and microbial communities that play important roles in nutrient cycling and CO2 exchange (Thurber et al. 2014).
[161] The PNW is a tectonically active region defined by the Cascadia Subduction Zone. Earthquakes and tsunamis are a major concern for the region.
[162] Notable submarine canyons: Juan de Fuca system, Grays Canyon, Astoria Canyon, Rogue Canyon; notable rocky banks: Laperouse, Swiftsure, Heceta, Nehalem, Stonewall, Coquille. Maps: Washington Marine Spatial Plan; USGS Expanding Pacific Research and Exploration of Submerged Systems; Office of Coast Survey.
[163] The upwelling driven by the Juan de Fuca Eddy creates one of the most productive habitats in the Northeastern Pacific and has high krill biomass concentration (Ware and Tomson 2005).
[164] Pinto abalone has a draft recovery plan in Washington State.

and are listed under both federal and state ESAs or are noted as state species of concern or strategy species;[165] salmon are a particularly vulnerable species with multiple stocks on federal and state lists. Commercial and recreational fishing is managed by state and/or federal agencies. Select species are subject to FMPs developed under the Pacific Fisheries Management Council (PFMC), while Tribal fisheries are conducted under the authority of Tribal governments.[166] Important habitat areas including EFH and HAPC are noted in FMPS, and green sturgeon have critical habitat in ocean and coastal bays and estuaries.[167] Many species have both economic and ecological importance.[168] Forage fish are especially important as prey for many higher trophic level species, and multiple species, particularly salmon, have significant cultural importance to PNW Tribes.

At least twenty species of elasmobranchs use benthic, nearshore, and pelagic waters off the PNW Coast.[169] Several species are management priorities under state and federal jurisdiction: big skates are an Oregon state strategy species, several species are on the IUCN Vulnerable and Endangered Species list,[170] and soupfin sharks are currently undergoing a review for federal ESA listing.[171] Little is known about species-specific sensory capacities (i.e., response to electrical and magnetic fields), critical habitat, foraging behavior and areas and migratory pathways for elasmobranchs in the PNW, as well as the fine-scale movements and habitat use of seasonally present species.[172] There are studies underway to address some of these data gaps, but there is a critical need for more elasmobranch research in the region.

Three species of sea turtles forage and migrate through PNW waters: green, leatherback, and loggerhead sea turtles.[173] All species are listed under federal and state ESAs. There is little information available about sea turtle use of the northern CCE, though leatherback presence appears correlated with productivity from the Columbia River plume and sea jelly aggregations (NMFS 2012). Leatherback sea turtle critical habitat extends from Southern Oregon to the US/Canada border.[174]

A minimum of 28 cetacean species utilize the northern CCE.[175] Very rarely, Arctic marine species may be found in PNW waters, with recent sightings of beluga whales and ringed seals in areas off Washington

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[165] For a summary of notable fish species in each state, see the Washington Marine Spatial Plan and Oregon Geographic Land Description.
[166] Fishing patterns vary between years depending on changes in the FMPs and environmental and economic conditions. Some fisheries are limited due to the vulnerable status of target species, such as groundfish and salmon.
[167] PFMC and NMFS have designated rockfish conservation areas in OR and WA that have varying restrictions for different fisheries: recreational, commercial, or specific types of fishing gear. EFH has been identified for coastal pelagic species (e.g. finfish and market squid), salmon, and highly migratory species (e.g. tuna, swordfish, sharks); 74 FR 52299: Final Rulemaking to Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon
[168] E.g., groundfish, salmonids, forage fish (small schooling fish such as smelt, sand lance, herring, anchovy, sardine).
[169] Oregon Shark Identification.
[170] Vulnerable: white shark, common thresher, shortfin mako; Endangered: basking shark. See IUCN Shark Specialist Group.
[171] NMFS: Tope shark.
[172] For example, migratory species like salmon sharks may change foraging behavior and preferred prey species while in PNW waters.
[173] While the northern CCE is not considered part of the range of Olive Ridley sea turtles, they have stranded on beaches in Oregon (Oregon Marine Mammal Stranding Network records) and are listed as Threatened on the state endangered species list.
[174] 77 FR 4169: Final Rule to Revise the Critical Habitat Designation for the Endangered Leatherback Sea Turtle.
[175] See NOAA Species Directory, West Coast region.

State. Multiple species are listed under state and/or federal ESAs or considered state strategic species.[176] Southern Resident killer whales and humpback whales have federally designated critical habitat in both states;[177] Foraging and migration Biologically Important Areas (BIAs) have been identified for humpback whales and gray whales off Oregon and Washington (Calambokidis et al. 2015).[178] BIAs do not capture all cetacean forging hotspots or important areas, or all species.[179] The extent of habitat use in the northern CCE by beaked whales, sei whales, sperm whales, and right whales is poorly understood, and individuals from migratory species that overwinter in the PNW may show unpredictable habitat use.[180] Small cetaceans may be present year-round, using both coastal and offshore areas for foraging, travel, socialization, and reproduction.[181] More information on stock structure is needed for many species;[182] more robust baseline distribution and abundance data is needed for all cetaceans, especially in offshore areas seaward of the continental shelf and in the winter and early spring.

Six species of pinnipeds and one species of sea otter use the northern CCE.[183] Northern sea otters are mainly found in Washington State. Guadalupe fur seals are listed under the federal ESA and Northern sea otters under the Washington ESA.[184] Pinnipeds forage and haul out in coastal areas and rocky offshore islands; breeding rookeries have been identified for Steller sea lions and harbor seals in Oregon and Washington.[185] Elephant seals and fur seals migrate through and forage in pelagic open ocean areas, including the continental shelf (Adachi et al. 2021).

[176] Federal ESA-listed species: blue whale, fin whale, two humpback whale Distinct Population Segments (DPS), North Pacific right whale, Southern Resident killer whale DPS, sperm whale, North Pacific gray whale DPS. Oregon and Washington ESA-listed species comprise the same species, though humpback and gray whales are not distinguished by DPS. Gray whales, harbor porpoises, and killer whales are Oregon strategic species; harbor porpoises are listed under the Washington ESA.

[177] 86 FR 41668: Revision of Critical Habitat for the Southern Resident Killer Whale Distinct Population Segment; 86 FR 21082: Designating Critical Habitat for the Central America, Mexico, and Western North Pacific Distinct Population Segments of Humpback Whales.

[178] Gray whales have both feeding and migration BIAs. BIAs are currently being updated by NMFS.

[179] Foraging opportunities and habitat use are strongly influenced by ocean and upwelling conditions, which may drive changes in distribution or suitable habitat (Fleming et al. 2016, Ingman et al. 2021). Heceta and Stonewall Bank and waters offshore Coos Bay and Cape Blanco are likely hotspots for large whales (Derville et al. 2022); more information is needed for areas seaward of the continental shelf.

[180] For example, a tagged Pacific Coast Foraging Group gray whale overwintered off Northern CA and the OR/CA border: Lagerquist et al. 2019.

[181] More information on the influence of ocean conditions on the distribution of small cetacean species is needed; at least some tropical and warm-temperate species may change distribution patterns with warming ocean temperatures in the CCE (Becker et al. 2018).

[182] There are three Distinct Population Segments of humpback whale in the CCE, with further separation into Demographically Independent Populations pending. Three small cetacean species in the CCE (orcas, harbor porpoises, and bottlenose dolphins) are divided into separate stocks with different home ranges. More species likely have distinct stocks that have not been designated yet.

[183] NOAA Species Directory, pinnipeds: Steller sea lions, California sea lions, Northern elephant seal, Northern fur seal, Guadalupe fur seal, and harbor seal.

[184] Guadalupe fur seals range as far north as Washington, with strandings observed regularly in Oregon and Washington; a recent Unusual Mortality Event impacted both Guadalupe and fur seals throughout the West Coast: emaciated and malnourished pups and yearlings attributed to poor prey conditions in the Pacific. Sea otters are rare in Oregon.

[185] Northern elephant seals primarily breed in California, but have established a small rookery at Cape Arago, Oregon, and births have occurred in Puget Sound, Washington (Hodder, Brown, and Cziesla, 1998).

Approximately 176 species of marine birds use coastal and offshore areas in the northern CCE, comprising millions of individuals.[186] This area provides forage sites (upwelling areas, river plumes, banks and reefs), nesting sites (sea stacks and rocky offshore islands, cliffs, bluffs, dunes, coastal beaches, old-growth coastal forests), and is part of the Pacific Flyway, a migratory pathway for millions of birds.

Approximately half of the West Coast seabird breeding population nests in the state of Oregon (Naughton et al. 2007). Estuaries provide crucial habitat for resident and migratory species. In Washington, the majority of seabird and shorebird populations are on the West Coast of the Olympic Peninsula. Distribution is broadly divided into coastal, continental shelf, and offshore regions, and many species use multiple areas depending on the season and activity (migrating, foraging, nesting) (Naughton et al. 2007, Speich and Wahl 1989). Important habitats and threats to seabirds in the northern CCE have been described by the US Fish and Wildlife Service (USFWS 2005). There are six marine birds listed under Federal or state ESAs.[187] An additional fourteen marine species have been identified as candidates for listing or as species of greatest conservation need in these states.[188] California brown pelicans, short-tailed albatrosses, California least tern, red knots, pink-footed shearwater, and western snowy plover may be particularly vulnerable to development in the CCE.

Seabird species spend most of their time over the open ocean or foraging below the surface. Many seabird species in the PNW are “central place foragers,” moving between breeding colonies nearshore and foraging in offshore areas.[189]

Sixteen bat species are found in the coastal areas of Oregon and Washington; six are considered strategy species in Oregon, including the hoary bat.[190] The use of offshore areas by bats in the PNW is unknown. Hoary bats likely migrate along the Pacific Coast and are found on offshore islands (Southeast Farallon Island); other species are found in the Channel Islands, suggesting some movement to offshore areas (Brown and Rainey 2018, Solick and Newman 2021)

As of December 2022, offshore wind development in Oregon and Washington are in early stages, though potential sites have been identified in both states and are pending public review: Oregon has published proposed Call Areas and one unsolicited lease request has been made in Washington. Oregon has the first wave energy research project in federal waters off Newport, Oregon, which began construction in 2021. The Southern Coast area of both states have been identified as more “suitable” areas due to wind speed (Musiel et al 2019, Van Cleve et al. 2013). Floating wind technology is more likely for both states due to water depth; however, Washington has also assessed other technologies closer to shore (Van Cleve et al. 2013).

[186] Seabirds, raptors, marsh birds, waterbirds, waterfowl, and shorebirds all rely on some part of the marine environment.
[187] Short-tailed albatross, California brown pelican, Western snowy plover, California least tern, marbled murrelet, and tufted puffin. Oregon endangered species list; Washington endangered species list.
[188] *Id.* and Oregon Strategy Species
[189] For example, Leach’s and fork-tailed storm petrels breed on islands but forage up to 200km away in offshore waters.
[190] The Western Bat Working Group defines the OR/WA region as “Marine Regime Mountains” and notes species with significant data gaps or high conservation concern.

Table 8. Monitoring priorities for the Pacific Northwest[191]

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
Comprehensive seafloor mapping, especially to identify rocky reef habitat and species composition[192]	Local, Sub-regional	Pre-, During, and Post-construction /Operation	Detailed benthic habitat surveys are needed pre-construction in offshore wind sites to identify biogenic habitats, classify important areas, and characterize areas of likely high ecological importance (e.g., Habitat Areas of Particular Concern or HAPCs). Continued monitoring during and post-construction is necessary to monitor disturbance, changes to rocky reef habitat, impacts to benthic fish habitat, and to monitor anchoring systems for impacts of developed sites.[193]	Geophysical surveys with sonar and multibeam ROV and AUV surveys Drop cameras Seabed sampling to identify bottom type and species present
Coastal and oceanic distribution and migration corridors for salmonids	Sub-regional, Regional	Pre-, During, and Post-construction /Operation	More information is needed on the oceanic distribution and habitat use of different species and stocks of salmon, to assess overlap with development areas and monitor impacts on salmon. salmon. Infrastructure may act as	Tagging (satellite, acoustic, biologging) to track movement and characterize behavior Fishery catch data (commercial, recreational, Tribal) can inform oceanic

[191] Regions are defined as: Local = Offshore wind project area and/or cable route. To identify direct impacts of development activities; Sub-regional = Adjacent habitat areas and/or Lease Areas. To identify cumulative impacts across multiple Lease Areas; Regional = Northeast Atlantic. To differentiate impacts of offshore wind from impacts from climate change or other factors.

[192] Work is underway by the USGS EXPRESS campaign to map deep-sea corals, chemosynthetic communities, and other sensitive habitats.

[193] It will also be important to understand how anchoring systems for floating offshore wind turbines impact benthic habitat and create sediment plumes to provide information for adaptive management if necessary.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			a fish aggregating device (FAD), a barrier to migration, or displace salmon from preferred habitat areas.	distribution and potential changes Underwater video monitoring Vessel surveys and sampling (net tows and trawling) Water turbulence to detect oceanographic changes
Distribution and habitat use of fish: Highly Migratory Species (HMS), Coastal Pelagic Species (CPS), and salmon	Local, Sub-regional, Regional	Pre-, During, Post-construction /Operation	Broad CPS and HMS distribution and habitat use depends on oceanographic conditions (temperature, productivity) and is variable on short, seasonal, and annual timescales.[194] Areas currently considered "low" or "high" abundance and Essential Fish Habitat (EFH) may change with ocean conditions, impacting the presence and habitat use of these species around infrastructure. Spatial density modeling can help inform changes in CPS and HMS abundance and presence and is needed to monitor EFH for these species.	Acoustic backscatter to identify large aggregations of CPS Personned aerial surveys for broad distribution Tagging (satellite, acoustic, biologging) for distribution and behavior characterization Fishery catch data (commercial, recreational, Tribal) and vessel surveys and sampling (net tows and trawling) can inform oceanic distribution and changes to distribution

[194] Short timescale changes within one upwelling system can affect fine-scale distribution of some CPS fish, changing distribution between days (Benoit-Bird, Waluk, and Ryan 2019).

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			More information is needed on the oceanic distribution and habitat use of different species and stocks of salmon to assess overlap with development areas and monitor impacts on salmon. Addition of floating offshore wind infrastructure to pelagic areas may act as fish aggregating devices, which may change distribution and/or catchability of these fish or displace them from preferred habitat areas.	
Movement patterns, foraging areas, and migration paths for key species (blue, thresher, white, mako and salmon sharks for pelagic species, big and long-nose skates for benthic species) Identify environmental drivers of habitat use Monitor movements in response to prey species (whiting, salmon, albacore	Sub-regional, Regional	Pre-construction	More information is needed on the occurrence and seasonality of sharks in the northern CCE, and when and where they migrate between different areas within and outside of the northern CCE. More data is needed to identify environmental drivers of seasonal presence and foraging opportunities as well as important foraging areas. The impact of offshore wind infrastructure on	Acoustic backscatter to monitor prey species Tagging (satellite, acoustic, biologging tags) Water turbulence monitoring around infrastructure Physical and biogeochemical modeling Biological sampling

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
tuna) distribution and identify important foraging areas for seasonally resident species (white and salmon sharks)			sharks and other elasmobranchs is unknown – the presence of floating infrastructure may displace from important foraging areas, act as a barrier to migration, or may act as an aggregating device for sharks and their prey, which may influence related risks like entanglement.	
Electromagnetic field (EMF) effects on species that detect bioelectric and magnetic fields, including sharks, rays, skates, Dungeness crabs, salmon, and green sturgeon	Local, Sub-regional	Pre-construction (lab); Post-construction /operation (field)	Baseline data is needed for these key CCE species to determine sensory thresholds and response to EMF fields and influence on movement patterns, foraging, and migratory paths. Lab-based studies will help develop standardized parameters and baseline species behaviors.[195]	Lab and field studies with video recording and biologging tags Direct measurements of EMF emitted from project-associated infrastructure and cables
Baseline abundance and distribution for large whales, including for less well-understood species (sei whales, sperm whales,	Local, Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Improved identification of locations of different (and potential) foraging areas, changing patterns of use, and environmental drivers of habitat use is needed to	Visual surveys (digital and personned aerial; vessel-based)[198] and infrared monitoring (vessel-based)

[195] Oregon State University recently received funding to conduct "non-invasive laboratory-based behavioral experiments in Longnose skate and Dungeness crab to quantify their minimum sensory thresholds, detection ranges, and behavioral responses to EMFs from HVCs." Biennial Projects 2022-2024.

[198] Incorporate and augment the CDFW RAMP surveys on large whale presence, abundance, and distribution: The CDFW Risk Assessment and Management Program (RAMP) monitors overlap of protected humpback and blue whales and leatherback sea turtles during the Dungeness crab fishing season; currently, risk assessments are conducted monthly starting in November through the end of the fishing season. By year 5 of the program, aerial surveys will occur monthly October-December and March-June.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
beaked whales, and North Pacific right whales), and including fine-scale habitat use for ESA-listed humpback, fin, and blue whales, and gray whales[196]			assess overlap with wind development areas and vessel traffic routes, and to monitor for displacement. More comprehensive monitoring and research efforts are needed to fill data gaps to inform baseline year-round occurrence of ESA-listed large whales and gray whales, including their presence and use of different habitat areas (coastal, continental slope, offshore), with a consideration for seasonal presences.[197] For vulnerable, poorly observed large whales with little information currently available, migration corridors, foraging areas, and environmental drivers of habitat use need to be identified to enable understanding of potential impacts from development.	Opportunistic sighting data[199] Tagging (satellite telemetry, biologging tags, accelerometer suction cup tags) to track broad and fine-scale habitat use and categorize behaviors Passive acoustic monitoring (archival, real-time)[200] Focal follows to assess changes in habitat use Photo-ID and DNA sampling to detect differences in abundance and distribution of distinct populations Environmental sampling Spatial density models, predictive habitat models to understand

[196] Eastern North Pacific gray whales are under an ongoing Unusual Mortality Event.
[197] Models such as the California Current Integrated Ecosystem Assessment incorporate environmental, biological, economic, and social indicators and assess short-term trends and long-term means. Current models include data from July-November; additional data is needed for winter-spring (December-June), particularly for the spring return from low latitude breeding areas, when foraging success is critical to nutrient intake. Fin whales have shown high residency to localized areas, and movement from shelf waters in the winter to offshore waters in the summer and have been observed overwintering off the California coast (Scales et al. 2017).
[199] From whale watch reports, citizen science programs.
[200] From autonomous vehicles, profile drifters, or moored surface buoy systems.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
				distribution and habitat suitability
Abundance and distribution of small cetaceans, particularly discrete populations of harbor porpoises, and CCE stocks of bottlenose dolphin, Risso's dolphin, and Dall's porpoise[201]	Sub-regional, Regional	Pre-, During, and Post-construction /Operation	Small cetacean population structure and abundance is not well known for most species, and there are spatial (offshore) and temporal (winter/spring) data gaps. More information is needed on environmental drivers of presence, distribution, and habitat use to assess when and where small cetaceans may occur in potential wind areas.[202] Discrete populations with limited ranges may be especially vulnerable to development in their habitat. More wide-ranging species that use offshore waters throughout the CCE may experience higher cumulative impacts from coastwide development.	Visual surveys (personned and digital aerial, vessel-based) and infrared monitoring (vessel-based) and opportunistic sightings data Tagging (satellite, biologging) for broad habitat distribution and to categorize behaviors Passive acoustic monitoring (archival, real-time) Photo identification to track individuals in distinct populations Spatial density models, predictive habitat models to understand distribution and habitat suitability
Distribution and fine-scale habitat use of pinnipeds	Local, Sub-regional, Regional[203]	Pre-, During, and Post-construction /Operation	Monitoring of presence and habitat use of pinnipeds, especially for haulout and rookery	Personned and digital aerial surveys for large-scale

[201] These species have identified CCE stocks; Dall's porpoise may be able to represent small cetaceans generally for life history and ecological function in ecological models (e.g. Washington Dept. of Fish and Wildlife Marine Spatial Plan).
[202] In addition, warm-temperate species not commonly present in the northern CCE may experience northward range shifts in response to warming ocean temperatures – their presence and habitat use should also be noted (e.g. false killer whales, striped dolphins, rough-toothed dolphins).
[203] Especially wide-ranging offshore pinnipeds (fur seals).

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			areas, is important to assess impacts from offshore wind development, including increased noise and disturbance, vessel traffic risk, changes in foraging behavior, and potential hearing threshold shifts. Assessing with environmental data can inform potential changes in habitat use and species health. Additional data is needed to fill data gaps on offshore habitat use and migration routes for wide-ranging species (fur seals, Northern elephant seals) to better assess potential impacts.	population counts and distribution Shore-based surveys for haulout and rookery locations and nearshore habitat use[204] Tagging (satellite, radio, biologging) to track movements of individuals and categorize behaviors Spatial density models, predictive habitat models
Abundance, distribution, habitat use patterns and oceanographic drivers for seabird, waterbird, shorebird, and landbird species species with limited information currently available, particularly threatened and	Local, Sub-regional, Regional	Pre-, During, and Post-construction	There are spatial and temporal data gaps in distribution and abundance across seasons and years, particularly related to offshore foraging areas and migration patterns/routes. In particular, more data is needed on the offshore habitat use of species that are small-bodied,	Visual surveys (personned and digital aerial, vessel-based) Infrared monitoring (aerial) for nocturnal detection Tagging (satellite, MOTUS,[210] automated nanotags, GPS, geolocators) provides information

[204] Including opportunistic sightings.
[210] MOTUS stations can be positioned on coastal and island locations off the West Coast, as well as on turbines.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
endangered species[205] Identify individual risk factors and overall species vulnerability to collision and displacement,[206] and assess the potential for changes under a range of likely oceanographic conditions that may affect distribution of seabirds and their prey, as well as transitory species (such as the Red Knot[207])			rare, declining, or forage nocturnally.[208] Oceanographic and forage fish data can be used to assess the influence on marine bird distribution and assess changes. Information on habitat use is important for species that may be more vulnerable to collision or displacement. Additional data is needed on behavior (e.g., flight height and strategy, time spent in rotor-swept zone)[209] and population status to update vulnerability rankings and assess risk. Identifying high density areas can support the	on occurrence, flight height and direction, and macro-scale displacement Marine radar to assess flight altitude, timing, and flux Acoustic receivers detect vocalizing birds Spatial distribution and predictive density models[211] Risk modeling[212] and energetic modeling

[205] Federally listed species and additional taxa that have been identified as species of conservation concern (USFWS 2021) will require particular attention. In the CCE, albatrosses are at varying stages of recovery and their high flights may make them especially vulnerable to collision. Furthermore, because Europe's offshore wind farms encompass marine habitats with few or no procellariiform seabirds present, we have no comparable studies even for making general inferences about the collision risks from offshore wind farms for the shearwaters, gadfly petrels, and other tubenoses that are common in the CCE.

[206] "Central place" foragers including Leach's and fork-tailed storm petrels may be displaced or impacted by development occurring between breeding islands and offshore foraging areas.

[207] Species with the highest collision vulnerability spend high percentages of time flying at the height of wind turbine blades (Kelsey et al 2018).; however, the distribution and behavior of species with lower collision vulnerability should be considered in assessing overall risk. For example, seabirds that traverse wind energy areas moving between nesting and foraging areas – changes in distribution or habitat use may impact collision vulnerability.

[208] Ashy storm petrels, alcids and albatrosses with nocturnal foraging habits have increased collision vulnerability; in the breeding season populations congregate on offshore islands and foraging movements are more restricted.

[209] For example, North Pacific albatrosses have low maneuverability in flight and sleep on the wing, increasing collision vulnerability.

[211] For example, Leirness et al. 2021.

[212] Update USGS/BOEM collision and displacement vulnerability database.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
			development of buffer zones. The potential impacts to transitory species are unknown but may be significant.	
Marbled Murrelet winter distribution	Regional	Pre-construction	More information is needed about wintering distribution and foraging patterns. In particular, there is a need to identify areas used during flightless fall molt period	Radio telemetry Marine radar to track large-scale movements between nesting areas and winter distribution
Monitoring of colony and nesting areas, especially for burrow nesters (Tufted puffins, storm petrels)	Local, Sub-regional	Pre-, During, and Post-construction /Operation	Tracking colony health and changes in use of nesting areas could indicate impacts from development in nearby areas. The productivity and abundance of burrow nesters may be difficult to monitor but indicate health of these populations	Visual surveys (personned and digital aerial, vessel-based) Infrared monitoring (aerial) for nocturnal detection Marine radar to assess flight altitude, timing, and flux Passive acoustic monitoring
Monitoring of marine birds with nocturnal habits:[213] Leach's storm petrel, Cassin's auklet, and Rhinoceros auklet; and other species	Local, Sub-regional, Regional	Pre- and Post-construction /Operation	More information is needed on the flight patterns and routes of marine birds that migrate, forage, or commute to foraging grounds at night (e.g., timing, altitude,	Marine radar to assess flight altitude, timing, and flux Infrared monitoring (aerial) for nocturnal detection

[213] Ashy storm petrels, alcids, and albatrosses with nocturnal foraging habits have increased collision vulnerability; in the breeding season populations congregate on offshore islands and foraging movements are more restricted.

Priority Topic	Scale	Time Period	Rationale	Tools/Techniques
including loons and terns that migrate through under low-light conditions			magnitude and direction) to understand species-specific exposure to potential impacts from offshore wind energy development. Information on the productivity and abundance of nocturnal foragers should be compared pre- and post-development to assess any changes.	Tagging (satellite, MOTUS, automated nanotags, GPS, geolocators) provides information on occurrence, flight height and direction Passive acoustic monitoring
Identification of bat species using coastal and offshore waters; abundance, distribution, and habitat use of coastal and offshore waters Environmental drivers of habitat use	Local, Sub-regional	Pre- and Post-construction /Operation	There is no baseline data for which species and their habitat use (migration, foraging, moving between foraging areas), activity rates, and movement of bats in offshore and coastal areas of the northern CCE. Basic information on species and activities is essential to assess the impacts of development. Environmental data for offshore migration and foraging conditions will be important to understand when and how bats might use offshore areas.	Infrared monitoring (aerial) for presence and flight information Tagging (satellite, radio,) and marine radar to track large-scale movements between land and offshore areas Acoustic receivers Prey sampling to assess foraging in offshore areas Environmental data to inform offshore migration conditions

c. Hawaii and Pacific Islands – forthcoming

IV. Great Lakes – forthcoming

Literature cited

Adachi, T., A. Takahashi, D.P. Costa, P.W. Robinson, L.A. Hückstädt, S.H. Peterson, R.R. Holser, R.S. Beltran, T.R. Keates, and Y. Naito. (2021). Forced into an ecological corner: Round-the-clock deep foraging on small prey by elephant seals. *Sci. Adv.* 7(20). https://doi.org/10.1126/sciadv.abg3628.

Adams, J., J. Felis, J. W. Mason, and J. Y. Takekawa. (2014). Pacific Continental Shelf Environmental Assessment (PaCSEA): aerial seabird and marine mammal surveys off northern California, Oregon, and Washington, 2011-2012. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region, Camarillo, CA. OCS Study BOEM 2014-003. 266 pages.

Bailey, H., K.L Brookes, and P.M. Thompson. 2014. Assessing environmental impacts of offshore wind farms: lessons learned and recommendationsfor the future. *Aquatic Biosystems*, vol. 10(1), pp. 1-13.

Battista, T., K. Buja, J. Christensen, J. Hennessey, K. Lassiter. (2017). Prioritizing Seafloor Mapping for Washington's Pacific Coast. *Sensors (Basel, Switzerland)*, *17*(4), 701. https://doi.org/10.3390/s17040701.

Becker, E.A., K.A. Forney, J.V. Redfern, J. Barlow, M.G. Jacox, J.J. Roberts, D.M. Palacios. (2018). Predicting cetacean abundance and distribution in a changing climate. *Diversity and Distributions* 25(4):626-643. https://doi.org/10.1111/ddi.12867.

Benoit-Bird, K. J., C.M. Waluk, and J.P. Ryan. (2019). Forage Species Swarm in Response to Coastal Upwelling. *Geophysical Research Letters* 46(3), 1537–1546. https://doi.org/10.1029/2018GL081603

Benson, S.R., T. Eguchi, D.G. Foley, K.A. Forney, H. Bailey, C. Hitipeuw, B.P. Samber, R.F. Tapilatu, V. Rei, P. Ramohia, J. Pita, and P.H. Dutton. (2011). Large-scale movements and high-use areas of western Pacific leatherback turtles, *Dermochelys coriacea*. *Ecosphere* 2(7):1-27. https://doi.org/10.1890/ES11-00053.1.

Bograd, S.J., I.D. Schroeder, N. Sarkar, X. Qiu, W.J. Sydeman, and F.B. Schwing. (2009). Phenology of coastal upwelling in the California Current. Geophysical Research Letters, 36.

Brandt, M.J., A. Diederichs, K. Betke, and G. Nehls. 2011. Responses of harbor porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series*, vol. 421, pp. 205-216.

Breuner, C.W., Sprague, R.S., Patterson, S.H., Woods, H.A. 2013. Environment, behavior and physiology: do birds use barometric pressure to predict storms? *J Exp Biol.* 216(Pt 11):1982-90. https://doi.org/10.1242/jeb.081067.

Brown, P.E. and W.E. Rainey, (2018). Bats of the California Channel Islands: New Records with new Methods, *Western North American Naturalist* 78(3), 474-495.

Buhl-Mortensen, L., A. Vanreusel, A.J. Gooday, L.A. Levin, I.G. Priede, P. Buhl-Mortensen, H. Gheerardyn, N.J. King, M. Raes. (2010). Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. *Marine Ecology* 31:21-50.

Burnett, J. D., L. Lemos, D. Barlow, M.G. Wing, T. Chandler, and L.G. Torres. (2019). Estimating morphometric attributes of baleen whales with photogrammetry from small UASs: A case study with blue and gray whales. *Mar. Mam. Sci*., 35 (1): 108-139. https://doi.org/10.1111/mms.12527

Calambokidis, J, G.H. Steiger, C. Curtice, J. Harrison, M.C. Ferguson, E. Becker, M. DeAngelis, and S.M. Van Parijs. (2015). Biologically Important Areas for Selected Cetaceans Within U.S. Waters – West Coast Region. *Aquatic Mammals* 41(1), 39-53.

Calambokidis, J., J. Laake, and A. Perez. (2019). Updated Analysis of abundance and population structure of season gray whales in the Pacific Northwest, 1996-2017. Final Report to NOAA, Seattle, Washington. pp. 1-72

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

Cavole, L.M., A.M. Demko, R.E. Diner, A. Giddings, I. Koester, C.M.L.S. Pagniello, M.-L. Paulsen, A. Ramirez-Valdez, S.M. Schwenck, N.K. Yen, M.E. Zill, and P.J.S. Franks. (2016). Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. *Oceanography* 29(2):273 285. https://doi.org/10.5670/oceanog.2016.32.

Chavez, F.P., M. Min, K. Pitz, N. Truelove, J. Baker, D. LaScala-Grunewald, M. Blum, K. Walz, C. Nye, A. Djurhuus, R.J. Miller, K.D. Goodwin, F.E. Muller-Karger, H.A. Ruhl, and C.A. Scholin. 2021. Observing life in the sea using environmental DNA. *Oceanography*, vol. 34, pp. 102–119.

Chen, X., S. E. Lohrenz, and D. A. Weisenberg. 2000. Distribution and controlling mechanisms of primary production on the Louisiana-Texas continental shelf. J. Mar. Syst.
25:179–207.

Chenillat, F., P.J.S. Franks, X. Capet, P. Rivière, N. Grima, B. Blanke, and V. Combes. (2018). Eddy properties in the Southern California Current System. *Ocean Dynamics* 68(7), 761-777. http://dx.doi.org/10.1007/s10236-018-1158-4.

Clipp, H.L., E.B. Cohen, J.A. Smolinsky, K.G. Horton, A. Farnsworth, and J.J. Buler. 2020. Broad-Scale Weather Patterns Encountered during Flight Influence Landbird Stopover Distributions. Remote Sensing 12:565. Multidisciplinary Digital Publishing Institute.

Conant, T.A., P.H. Dutton, T. Eguchi, S.P. Epperly, C.C. Fahy, M.H. Godfrey, S.L. MacPherson,
Dahl, T.E. 2011. Status and trends of wetlands in the conterminous United States 2004 to 2009. U.S. Department of the Interior; Fish and Wildlife Service, Washington, D.C. 108 pp.

Conant, T., P. Dutton, T. Eguchi, S.P. Epperly, C.C. Fahy, M.H. Godfrey, S. L. MacPherson, E.E. Possardt, B.A. Shroeder, J.A. Seminoff, M.L. Snover, C.M. Upite, and B.E. Witherington. 2009. Loggerhead sea turtle (Caretta caretta) 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service, August 2009. 222 pages.

Curtice, C., Cleary, J., Shumchenia, E., and Halpin, P. (2019). Marine-Life Data and Analysis Team (MDAT) Technical report on the methods and development of marine-life data to support regional ocean planning and management. http://seamap.env.duke.edu/models/MDAT/MDAT-TechnicalReport.pdf

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., Sunderleyer, J., and Siebert, U. (2013). Effects of pile-driving on harbor porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. *Environmental Research Letters*, vol. 8, p. 025002.

Dame, R, M. Alber., D. Allen, M. Mallin, C. Montague, A. Lewitus, A. Chalmers, R. Gardner, C. Gilman, B. Kjerfve, J. Pinckney, and N. Smith. 2000. Estuaries of the South Atlantic Coast of North America: Their Geographical Signatures. Estuaries. 23(6): 793- 819.

Davis, G.E., Baumgartner, M.F., Bonnell, J.M. *et al.* Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. *Sci Rep* **7**, 13460 (2017). https://doi.org/10.1038/s41598-017-13359-3

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

Derville, S., D.R. Barlow, C. Hayslip, L.G. Torres. (2022). Seasonal, Annual, and Decadal Distribution of Three Rorqual Whale Species Relative to Dynamic Ocean Conditions Off Oregon, USA. *Front. Mar. Sci.* 9:868566.

Di Lorenzo, E., V. Combes, J.E. Keister, P.T. Strub, A.C. Thomas, P.J.S. Franks, M.D. Ohman, J.C. Furtado, A. Bracco, S.J. Bograd, W.T. Peterson, F.B. Schwing, S. Chiba, B. Taguchi, S. Hormazabal, and C. Parada. (2013). Synthesis of Pacific Ocean climate and ecosystem dynamics. *Oceanography* 26(4):68–81. https://doi.org/10.5670/oceanog.2013.76.

Duin, M., (2019). Effect of wind farms at the North Sea on meteorological conditions in the Netherlands. M.S. thesis. Meteorology - Master Earth and Environment (2021) - Meteorology and Air Quality - Wageningen University.

Elise, S., Urbina-Barreto, I., Pinel, R., Mahamadaly,V., Bureau, S., Penin, L., Adjeroud, M., Kulbicki M., Bruggemann, J.H. (2019). Assessing key ecosystem functions through soundscapes: A new perspective from coral reefs. *Ecological Indicators*, vol. 107, p. 105623.

Estabrook, B. J., K. B. Hodge, D. P. Salisbury, D. Ponirakis, D. V. Harris, J. M. Zeh, S. E. Parks, A. N. Rice. 2019. Year-1 Annual Survey Report for New York Bight Whale Monitoring Passive Acoustic Surveys October 2017- October 2018. Contract C009925. New York State Department of Environmental Conservation. East Setauket, NY.

Fautin, D., P. Dalton, L.S. Incze, J.C. Leong, C. Pautzke, A. Rosenberg, P. Sandifer, G. Sedberry, J.W. Tunnell, Jr., I Abbott, R.E. Brainard, M. Brodeur, L.G. Eldredge, M. Feldman, F. Moretzsohn, P.S. Vroom, M. Wainstein, and N. Wolff. 2010. An Overview of Marine Biodiversity in United States Waters. PloS One, 5(8): 1-47.

Fiechter, J., C.A. Edwards, and A.M. Moore. (2018). Wind, circulation, and topographic effects on alongshore phytoplankton variability in the California Current. *Geophysical Research Letters* 45(7), 3238–3245. https://doi.org/10.1002/2017GL076839.

Fleming A.H., C.T. Clark, J. Calambokidis, J. Barlow. (2016). Humpback whale diets respond to variance in ocean climate and ecosystem conditions in the California Current. *Glob Chang Biol.*(22)3:1214-24. doi: 10.1111/gcb.13171. Epub 2015 Dec 30. PMID: 26599719.

Ford, R.G., S. Terrill, J. Casey, D. Shearwater, S.R. Schneider, L.T. Balance, L. Terrill, M. Tollefson, and D.G. Ainley. (2021). Distribution patterns and population size of the Ashy Storm Petrel *Oceanodroma homochroa*. *Marine Ornithology* 49(2): 193–204.

Gangopadhyay, A., G. Gawarkiewicz, E.N.S. Silva, M. Monim, and J. Clark. An Observed Regime Shift in the Formation of Warm Core Rings from the Gulf Stream. Sci Rep 9, 12319 (2019). https://doi.org/10.1038/s41598-019-48661-9.

García-Reyes, M., and J. Largier. 2010. Observations of increased wind-driven coastal upwelling off central California. *J. Geophys. Res.*,115, C04011.

Goebel, N.L., C.A. Edwards, J.P. Zehr, and M.J. Follows, (2010). An emergent community ecosystem model applied to the California Current System. Journal of Marine Systems, 83(3-4), 221-241. https://doi.org/10.1016/j.jmarsys.2010.05.002.

Goldfinger C, S.K. Henkel, C. Romsos, A. Havron, and B. Black. (2014). Benthic Habitat Characterization Offshore the Pacific Northwest Volume 1:Evaluation of Continental Shelf Geology. US Dept. of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region. OCS Study BOEM 2014-662.161 pp.

Haase, P., J.D. Tonkin, S. Stoll, B. Burkhard, M. Frenzel, I.R. Geijzendorffer, C. Häuser, S. Klotz, I. Kühn, W.H. McDowell, and M. Mirtl. (2018). The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. *Science of the Total Environment*, vol. 613, pp. 1376-1384.

Hanel, R., L. Marohn, and H. Westerberg. (2022). No new evidence for an Atlantic eels spawning area outside the Sargasso Sea. Sci Rep 12, 11778. https://doi.org/10.1038/s41598-022-14882-8.

Hare J.A., W.E. Morrison, M.W. Nelson M.M. Stachura, E.J. Teeters, R.B. Griffis, M.A. Alexander, J. D. Scott, L. Alade, R. J. Bell, A. S. Chute, K. L. Curti, T. H. Curtis, D. Kircheis, J.F. Kocik, S.M. Lucey, C.T. McCandless, L.M. Milke, D.E. Richardson, E. Robillard, H.J. Walsh, M.C. McManus, K.E. Marancik, and C.A. Griswold. (2016) A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLOS ONE 11(2): e0146756.

Hatfield, B.B., J.L. Yee, M.C. Kenner, and J.A. Tomoleoni. (2019). California sea otter (*Enhydra lutris nereis*) census results, spring 2019: *U.S. Geological Survey Data Series* 1118, 12 p. https://doi.org/10.3133/ds1118.

Henry A.E., J.E. Moore, J. Barlow, J. Calambokidis, L.T. Ballance, L. Rojas-Bracho, J. Urbán Ramírez. (2020). Report on the California Current Ecosystem Survey (CCES): Cetacean and Seabird Data Collection Efforts, June 26 – December 4, 2018, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-636. https://doi.org/10.25923/0wyw-s486.

Hodder, J., R.F. Brown, and J. Cziesla. (1998). "The Northern Elephant Seal in Oregon: A Pupping Range Extension and Onshore Occurrence." *Marine Mammal Science,* 14(4):873-881.

Holdman, A.K., J.H. Haxel, H. Klinck, and L..G. Torres. (2019). Acoustic monitoring reveals the times and tides of harbor porpoise (*Phocoena phocoena*) distribution off central Oregon, U.S.A. *Marine Mammal Science* (35): 1, 164-186. https://doi.org/10.1111/mms.12537.

Hopkins-Murphy, S. R., Owens, D. W., and T.M Murphy. (2003). Ecology of immature loggerheads on foraging grounds and adults in internesting habitat in the eastern United States. *Loggerhead sea turtles*, *1*, 79-92.

Horton K.G., B.M.V. Doren, F.A.L. Sorte, E.B. Cohen, H.L. Clipp, J.J. Buler, D. Fink, J.F. Kelly, and A. Farnsworth. (2019). Holding steady: Little change in intensity or timing of bird migration over the Gulf of Mexico. Global Change Biology 25:1106–1118.

Huang, H.Y., and A. Hall. (2015). Preliminary assessment of offshore wind development impacts on marine ecosystems. CEC-500-2016-023. Report by University of California Los Angeles (UCLA). Report for California Energy Commission.

Ingman K, E. Hines, P.L.F. Mazzini, R.C. Rockwood, N. Nur, J. Jahncke. (2021). Modeling changes in baleen whale seasonal abundance, timing of migration, and environmental variables to explain the sudden rise in entanglements in California. *PLoS ONE* 16(4): e0248557. https://doi.org/10.1371/journal.pone.0248557.

Inspire Environmental, (2020). *South Fork Wind Benthic Habitat Mapping to Support Essential Fish Habitat Consultation*, at 15. https://www.boem.gov/sites/default/files/documents/about-boem/AppN2_SFW_HabitatMapping_Report_2020-06-16.pdf.

Jacox, M.G., S.J. Bograd, E.L. Hazen, and J. Fiechter. (2015). Sensitivity of the California Current nutrient supply to wind, heat, and remote ocean forcing. *Geophysical Research Letters* 42(14), 5950-5957. https://doi.org/10.1002/2015GL065147.

Jacox, M.G., E.L. Hazen, and S.J. Bograd. (2016). Optimal environmental conditions and anomalous ecosystem responses: Constraining bottom-up controls of phytoplankton biomass in the California Current System. *Scientific Reports* 6. https://doi.org/10.1038/srep27612.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack and B. Würsig. (2008). Sperm whale seismic study in the Gulf of Mexico: Synthesis report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana. OCS Study MMS 2008-006. 341pp.

Jones, T., J.K. Parrish. A.E. Punt. V.L. Trainer. R. Kudela. J. Lang. M.S. Brancato. A. Odell. B. Hickey. 2017. Mass mortality of marine birds in the Northeast Pacific caused by *Akashiwo sanguinea. Marine Ecology Progress Series,* 579:111–127.

Jones, T., J.K. Parrish, W.T. Peterson, E.P. Bjorkstedt, N.A. Bond, and L.T. Balance, V. Bowes, J.M. Hipfner, H.K. Burgess, J.E. Dolliver, K. Lindquist, J. Lindsey, H.M. Nevins, R.R. Robertson, J. Roletto, L. Wilson, T. Joyce, and J. Harvey. (2018). Massive mortality of a planktivorous seabird in response to a marine heatwave. *Geophysical Research Letters*,45, 3193–3202. https://doi.org/10.1002/2017GL076164.

Kanive, P.E., J.J. Rotella, T.K. Chapple, S.D. Anderson, T.D. White, B.A. Block, S.J. Jorgensen. (2021). Estimates of regional abundance and population growth rates of white sharks of central California. *Biological Conservation*, 257, 109104.

Kelsey, E.C., J.J. Felis, M. Czapanskiy, D.M. Pereksta, and J. Adams. (2018). Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific Outer Continental Shelf. *J Environ Manage.* 1(227):229-247. https://doi.org/10.1016/j.jenvman.2018.08.051.

Kenney, R.D. and Vigness-Raposa, K.J., (2010). *Technical report 10. Marine mammals and sea turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and nearby waters: An analysis of existing data for the Rhode Island Ocean Special Area Management Plan. Rhode Island coastal resources management program/Ocean Special Area Management Plan (Ocean SAMP)*. Draft report. Wakefield, Rhode Island: Rhode Island Coastal Resources Management Council. Appendix A, pp. 634-970.

Khan, A.A., and Smith, K. (2020). *Seafloor Disturbance and Recovery Monitoring at the Block Island Wind Farm*, BOEM, at 27-28. https://espis.boem.gov/final%20reports/BOEM_2020-019.pdf.

King, J.R., V.N. Agostini, C.J. Harvey, G.A. McFarlane, M.G.G. Foreman, J.E. Overland, E. Di Lorenzo, N. A. Bond, K.Y. Aydin. (2011). Climate forcing and the California Current ecosystem, *ICES Journal of Marine Science* (68):6, 1199–1216. https://doi.org/10.1093/icesjms/fsr009.

Kraus, S.D., S. Leiter, K. Stone, B. Wikgren, C. Mayo, P. Hughes, R.D. Kenney, C.W. Clark, A.N. Rice, B. Estabrook, and J. Tielens. (2016). *Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles*. OCS Study BOEM 2016-054. Sterling, Virginia: US Department of the Interior, Bureau of Ocean Energy Management.

Kraus, S.D., R.D. Kenney, and L. Thomas. (2019). *A framework for studying the effects of offshore wind development on marine mammals and turtles*. Report prepared for the Massachusetts Clean Energy Center, Boston, MA, 2110. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Renewable-Energy/A-Framework-for-Studying-the-Effects.pdf.

Kress, S.W., P. Shannon, and C. O'Neal. (2016). Recent changes in the diet and survival of Atlantic puffin chicks in the face of climate change and commercial fishing in midcoast Maine, USA. *Facets*, *1*(1), pp.27-43.

Kritzer, J.P., M. DeLucia, E. Greene, C. Shumway, M.F. Topolski, J. Thomas-Blate, L.A. Chiarella, K.B. Davy, and K. Smith. (2016). The Importance of Benthic Habitats for Coastal Fisheries, *BioScience*, Volume 66, Issue 4, Pages 274–284, https://doi.org/10.1093/biosci/biw014

LaBrecque, E., C. Curtice, J. Harrison, S.M.V. Parijs, and P.N. Halpin. (2015). Biologically important areas for cetaceans within U.S. waters – East Coast region. *Aquatic Mammals,* vol. 41, pp. 17-29.

Lagerquist, B.A., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, B.R. Mate. (2019). Feeding home ranges of Pacific Coast Feeding Group gray whales. *Journal of Wildlife Management*, 83(4):925-937. Doi: 10.1002/jwmg21642

Laidig, T., D. Watters, N. Prouty, M. Everett, L. Duncan, L. Clarke, C. Caldow, A. W.J. Demopoulos. (2021). A characterization of deep-sea coral and sponge communities along the California and Oregon coast using a remotely operated vehicle on the EXPRESS 2018 expedition: A report to NOAA Deep-sea Coral Research and Technology Program. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-657. https://doi.org/10.25923/sd6f-j739.

Leirness, J.B., J. Adams, L.T. Ballance, M. Coyne, J.J. Felis, T. Joyce, D.M. Pereksta, A.J. Winship, C.F.G. Jeffrey, D. Ainley, D. Croll, J. Evenson, J. Jahncke, W. McIver, P.I. Miller, S. Pearson, C. Strong, W. Sydeman, J.E. Waddell, J.E. Zamon, J. Christensen. (2021). Modeling at-sea density of marine birds to support renewable energy planning on the Pacific Outer Continental Shelf of the contiguous United States. Camarillo (CA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-014. 385 p.

Leiter, S.M., K.M. Stone, J.L. Thompson, C.M. Accardo, B.C. Wikgren, M.A. Zani, T.V.N. Cole, R.D. Kenney, C.A. Mayo, and S.D. Kraus. (2017). North Atlantic right whale Eubalaena glacialis occurrence in offshore wind energy areas near Massachusetts and Rhode Island, USA. *Endangered Species Research*, vol. 34, pp. 45–59.

Likens, G. and Lindenmayer, D., (2018). *Effective ecological monitoring*. CSIRO publishing.

Lindeboom, H., S. Degraer, J. Dannheim, A.B. Gill, and D. Wilhelmsson. (2015). Offshore wind park monitoring programmes, lessons learned and recommendations for the future. *Hydrobiologia*, vol. 756, pp. 169-180.

Loring P.H., A.K. Lenske, J.D. McLaren, M. Aikens A.M. Anderson, Y. Aubrey, E. Dalton, A. Dey, C. Friis, D. Hamilton, B. Holberton, D. Kriensky, D. Mizrahi, L. Niles, K.L. Parkins, J. Paquet, F. Sanders, A. Smith, Y. Turcotte, A. Vitz, and P.A. Smith. (2020). Tracking Movements of Migratory Shorebirds in the US Atlantic Outer Continental Shelf Region. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-008. 104 p.

Lyons, J.E., M. C. Runge, H.P. Laskowski, W.L. Kendall. (2008). Monitoring in the context of structured decision-making and adaptive management. *The Journal of Wildlife Management*, vol. 72, pp. 1683-1692.

Malone, T.C., T.S. Hopkins, P.G. Falkowski, and T.G. Whitledge. (1983) Production and transport of phytoplankton biomass over the continental shelf of the new york bight, Continental Shelf Research, Vol. 1, Issue 4, Pp. 305-337, https://doi.org/10.1016/0278-4343(83)90001-8.

Marsh, R., and E. van Sebille, Eds. (2021). Chapter 5 – Eastern boundary currents, upwelling, and high biological productivity. Ocean Currents: Physical Drivers in a Changing World. *Elsevier*.

Martien, K.K., B.L. Taylor, F. I. Archer, K. Audley, J. Calambokidis, T. Cheeseman, J. De Weerdt, A. F. Jordán, P. Martínez-Loustalot, C.D. Ortega-Ortiz, E. M. Patterson, N. Ransome, P. Ruvelas, J. U. Ramírez, F. Villegas-Zurita. (2021). Evaluation of Mexico Distinct Population Segment of Humpback Whales as units under the Marine Mammal Protection Act. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-658. https://doi.org/10.25923/nvw1-mz45.

Menza, C., J. Leirness, T. White, A. Winship, B. Kinlan, L. Kracker, J.E. Zamon, L. Ballance, E. Becker, K.A. Forney, J. Barlow, J. Adams, D. Pereksta, S. Pearson, J. Pierce, S. Jeffries, J. Calambokidis, A. Douglas, B. Hanson, S.R. Benson and L. Antrim. (2016). Predictive mapping of seabirds, pinnipeds and cetaceans off the Pacific Coast of Washington. NOAA Technical Memorandum NOS NCCOS 210. Silver Spring, MD. 96 pp. https://doi.org/10.7289/V5NV9G7Z.

Meyer-Gutbrod, E.L., C.H. Greene, and K.T.A. Davies. (2018). Marine species range shifts necessitate advanced policy planning: The case of the North Atlantic right whale. Oceanography 31(2):19–23. https://doi.org/10.5670/oceanog.2018.209.

Miles, T., S. Murphy, J. Kohut, S. Borsetti, D. Munroe. (2021). Offshore Wind Energy and the Mid-Atlantic Cold Pool: A Review of Potential Interactions. Marine Technology Society Journal, 55(4), 72-87. https://doi.org/10.4031/MTSJ.55.4.8.

Musial, W., P. Beiter, S. Tegen, and A. Smith. (2016). Potential Offshore Wind Energy Areas in California: An Assessment of Locations, Technology, and Costs. NREL Technical Report, No. NREL/TP-5000-67414.

Musial, Walter, P. Beiter, J. Nunemaker, D. Heimiller, J. Ahmann, and J. Busch. (2019). Oregon Offshore Wind Site Feasibility and Cost Study. NREL/TP-5000-74597. https://www.boem.gov/BOEM-2019-046/
National Academies of Sciences, Engineering, and Medicine. (2017). Approaches to Understanding the Cumulative Effects of Stressors on Marine Mammals. Washington, DC: The National Academies Press. https://doi.org/10.17226/23479.

National Marine Fisheries Service. (2012). Final Rule to Revise the Critical Habitat Designation for Leatherback Sea Turtles. Final Biological Report. NMFS Southwest Fisheries Science Center. https://media.fisheries.noaa.gov/dam-migration/leatherback_criticalhabitat_biological-508.pdf.

National Academies of Sciences, Engineering, and Medicine. (2017). Approaches to Understanding the Cumulative Effects of Stressors on Marine Mammals. Washington, DC. The National Academies Press. https://doi.org/10.17226/23479.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. Kemp's Ridley Sea Turtle (Lepidochelys Kempii) 5-Year Review: Summary and Evaluation. https://repository.library.noaa.gov/view/noaa/17048

National Marine Fisheries Service and U.S. Fish and Wildlife Service. (2020). Endangered Species Act status review of the leatherback turtle (Dermochelys coriacea). Report to the National Marine Fisheries Service Office of Protected Resources and U.S. Fish and Wildlife Service.

National Marine Fisheries Service. 2021. Revision of the Critical Habitat Designation for the Southern Resident killer whales: Final Biological Report. NMFS West Coast Region. https://repository.library.noaa.gov/view/noaa/31587.

Naughton, M., D. Pitkin, R. Lowe, and K. So. (2007). Catalog of Oregon Seabird Colonies Biological Technical Publication (Report No. BTP-R1009-2007). Report by U.S. Fish and Wildlife Service (USFWS).

NMFS-NEFSCa, *Omnibus Essential Fish Habitat Amendment 2, Volume 2 EFH and HAPC Designation Alternatives and Environmental Impacts*, at 13-14, 19, 24-25, 36-41, 52-54. https://www.habitat.noaa.gov/application/efhmapper/oa2_efh_hapc.pdf#page=18.

NMFS-NEFSCb, *Operational Assessment of 19 Northeast Groundfish Stocks*, at 31, 72, 167, 177, 195. https://repository.library.noaa.gov/view/noaa/16091.

NOAA. (2005). A Biogeographic Assessment of the Channel Islands National Marine Sanctuary: A Review of Boundary Expansion Concepts for NOAA's National Marine Sanctuary Program, NOAA Technical Memorandum NOS NCCOS 21. https://repository.library.noaa.gov/view/noaa/2161.

NOAA. (2016). Waring, Gordon T. (ed.), et al. US Atlantic and Gulf of Mexico marine mammal stock assessments - 2015. Northeast Fisheries Science Center (U.S.). NOAA technical memorandum NMFS-NE ; 238. DOI : http://doi.org/10.7289/V57S7KTN

NOAA. (2019). COMMON BOTTLENOSE DOLPHIN (Tursiops truncatus truncatus): Northern Gulf of Mexico Bay, Sound, and Estuary Stocks. https://media.fisheries.noaa.gov/dam-migration/170_tm258_bottlenosebse.pdf

NOAA. (2021). Hayes, Sean A.(Sean Arthur) (ed.), et al. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2020. Northeast Fisheries Science Center (U.S.). NOAA technical memorandum NMFS-NE; 271. https://doi.org/10.25923/nbyx-p65.

NOAA. (2022). Garrison, L., "The Trophic Ecology and Habitat of the Endangered Gulf of Mexico Bryde's Whale (Balaenoptera edeni)," online webinar. https://restoreactscienceprogram.noaa.gov/projects/rices-whales.

NOAA California Current Integrated Ecosystem Assessment Team (CCIEA). 2021-2022 California Current Ecosystem Status Report, a report to the Pacific Fishery Management Council, March 13, 2022. Ed. Dr. Chris Harvey, Dr. Toby Garfield, Mr. Greg Williams, and Dr. Nick Tolimieri. https://www.pcouncil.org/documents/2022/02/h-2-a-cciea-team-report-1-2021-2022-california-current-ecosystem-status-report-and-appendices.pdf/.

O'Brien, O., K. McKenna, B. Hodge, D. Pendleton, M. Baumgartner, and J. Redfern. (2021). *Megafauna aerial surveys in the Wind Energy Areas of Massachusetts and Rhode Island with emphasis on large whales*. Summary Report - Campaign 5, 2018-2019. Agreement No.: M17AC00002. OCS Study BOEM 2021-033. US Department of the Interior, Bureau of Ocean Energy Management.

Office of National Marine Sanctuaries. (2020). Flower Garden Banks National Marine Sanctuary Expansion Final Environmental Impact Statement. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. https://nmsflowergarden.blob.core.windows.net/flowergarden-prod/media/archive/doc/expansion/fgbnmsexpansionfeis.pdf

Paton PWC, C. Cooper-Mullin, S. Kouhi, P.H. Loring, J. Moore, J. Miller, and G. Potty. (2021). Assessing movements of birds using digital VHF transmitters: A validation study. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-009. 222 p.

Pauly, D., and V. Christensen. (1995). Primary production required to sustain global fisheries. *Nature* 374:255–257. https://doi.org/10.1038/374255a0.

Pershing, A.J., M.A. Alexander, D.C. Brady, D. Brickman, E.N. Curchitser, A.W. Diamond, L. McClenachan, K.E. Mills, O.C. Nichols, D.E. Pendleton, and N.R. Record. (2021). Climate impacts on the Gulf of Maine ecosystem: A review of observed and expected changes in 2050 from rising temperatures. *Elementa: Science of the Anthropocene*, vol. 9, p. 00076.

Peterson, T.S, S.K. Pelletier, and M. Giovanni. (2016). *Long-Term Bat Monitoring on Islands, Offshore Structures, and Coastal Sites in the Gulf of Maine, Mid-Atlantic, and Great Lakes—Final Report*. Topsham, ME, USA. Prepared for the U.S. Department of Energy; Bird Studies Canada 2018.

Piatt J.F., J.K. Parrish, H.M. Renner, S.K. Schoen, T.T. Jones, M.L. Arimitsu, K.J. Kuletz, B. Bodenstein, M.G. Garcia-Reyes, R.S. Duerr, R.M. Corcoran, R.S.A. Kaler, G.J. McChesney, R.T. Golightly, H.A. Coletti, R.M. Suryan, H.K. Burgess, J. Lindsey, K. Lidquist, P.M. Warzybok, J. Jahncke, J. Roletto, and W.J. Sydeman. (2020). Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016. PLOS ONE 15(1). https://doi.org/10.1371/journal.pone.0226087.

Possardt, E.E., B.A. Schroeder, J.A. Seminoff, M.L. Snover, C.M. Upite, and B.E. Witherington. (2009). Loggerhead sea turtle (Caretta caretta) 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service, August 2009. 222 pages.

Priest, Tyler. (2005)."A perpetual extractive frontier? The history of offshore petroleum in the Gulf of Mexico." *Nature, raw materials, and political economy*. Emerald Group Publishing Limited

Quintana-Rizzo E., S. Leiter, T.V.N. Cole, M.N. Hagbloom, A.R. Knowlton, P. Nagelkirk, O. O'Brien, C.B. Khan, A.G. Henry, P.A. Duley, L.M. Crowe, C.A. Mayo, and S.D. Kraus. (2021). Residency, demographics, and movement patterns of North Atlantic right whales Eubalaena glacialis, in an offshore wind energy development in Southern New England, USA, *Endangered Species Research*, vol. 45, pp. 251-268.

Rabalais, N. N. (1990). Biological communities of the south Texas continental shelf. *American Zoologist*, *30*(1), 77-87.

Rabalais, N. N., and Turner, R. E. (2019). Gulf of Mexico hypoxia: Past, present, and future. *Limnology and Oceanography Bulletin*, *28*(4), 117-124.

Raghukumar, K., C. Chartrand, G. Chang, L. Cheung, and J. Roberts. (2022). Effect of Floating Offshore Wind Turbines on Atmospheric Circulation in California. *Front. Energy Res.* 10:863995. https://doi.org/10.3389/fenrg.2022.863995.

Roberts, S.M., A.M. Boustany, and P.N. Halpin. (2020). Substrate-dependent fish have shifted less in distribution under climate change. *Commun Biol* 3, 586. https://doi.org/10.1038/s42003-020-01325-1.

Rockwood, R.C., Elliott, M.L., Saenz, B., Nur, N., Jahncke, J. 2020. Modeling predator and prey hotspots: Management implications of baleen whale co-occurrence with krill in Central California. *PLoS ONE* 15(7): e0235603. https://doi.org/10.1371/journal.pone.0235603.

Rogers, S.G., T.E.Targett, and S.B. Van Sant. 1984. Fish-Nursery Use in Georgia Estuaries: The Influence of Springtime Freshwater Conditions. Transactions of the American Fisheries Society, 113:595-606.

Ruckelshaus, M., Klinger, T., Knowlton, N. and D.P. DeMaster. (2008). Marine ecosystem-based management in practice: scientific and governance challenges. *BioScience*, vol. 58, pp. 53-63.

Ruggiero, P., M.G. Kratzmann, E.A. Himmelstoss, D. Reid, J. Allan, and G. Kaminsky. (2013). National assessment of shoreline change: Historical shoreline change along the Pacific Northwest coast (Open-File Report No. 2012–1007) (p. 62). U.S. Department of the Interior, U.S. Geological Survey. http://pubs.usgs.gov/of/2012/1007/.

Ryan, J.P., K.J. Benoit-Bird, W.K. Oestreich, P. Leary, K.B. Smith, and C.M. Waluk, D.E. Cade, J.A. Fahlbusch, B.L. Southall, J.E. Joseph, T. Margolina, J. Calambokidis, A. DeVogelaere, J.A. Goldbogen. (2022). Oceanic giants dance to atmospheric rhythms: Ephemeral wind-driven resource tracking by blue whales. *Ecology Letters*, 25, 2435–2447. https://doi.org/10.1111/ele.14116.

Saba, V. S., S.M. Griffies, W.G. Anderson, M. Winston, M.A. Alexander, T.L. Delworth, J.A. Hare, M.J. Harrison, A. Rosati, G.A. Vecchi, and R. Zhang. (2016), Enhanced warming of the Northwest Atlantic Ocean under climate change, *J. Geophys. Res. Oceans*, 121, 118–132.

Samhouri, J.F., A.J. Haupt, P.S. Levin, J.S. Link, and R. Shuford. (2014). Lessons learned from developing integrated ecosystem assessments to inform marine ecosystem-based management in the USA. *ICES Journal of Marine Science*, vol. 71, pp. 1205-1215.

Sammarco, P. W., Kolian, S. R., Warby, R. A., Bouldin, J. L., Subra, W. A., & Porter, S. A. (2013). Distribution and concentrations of petroleum hydrocarbons associated with the BP/Deepwater Horizon Oil Spill, Gulf of Mexico. *Marine pollution bulletin*, *73*(1), 129-143.

Santora, J.A., E.L. Hazen, I.D. Schroeder, S.J. Bograd, K.M. Sakuma, and J.C. Field. (2017). Impacts of ocean climate variability on biodiversity of pelagic forage species in an upwelling ecosystem. *Marine Ecology Progress Series*, vol. 580, pp. 205-220.

Santora, J.A., W.J. Sydeman, I.D. Schroeder, J.C. Field, R.R. Miller, and B.K. Wells. (2017). Persistence of trophic hotspots and relation to human impacts within an upwelling marine ecosystem. *Ecological Applications* 27(2): 560–574. https://doi.org/10.1002/eap.1466.

Santora, J.A., R. Zeno, J.G. Dorman, and W.J. Sydeman. (2018). Submarine canyons represent an essential habitat network for krill hotspots in a Large Marine Ecosystem. *Sci Rep* 8: 7579. https://doi.org/10.1038/s41598-018-25742-9.

Santora, J.A., N.J. Mantua, I.D. Schroeder, J.C. Field, E.L. Hazen, S.J. Bograd, W.J. Sydeman, B.K. Wells, J. Calambokidis, L. Saez, D. Lawson, K.A. Forney. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. *Nat Commun.* (11) 536. https://doi.org/10.1038/s41467-019-14215-w.

Savidge, D. K. and J. A. Austin. (2007). The Hatteras Front: August 2004 velocity and density structure, J. Geophys. Res., 112, C07006.

Scales, K.L., G.S. Schorr, E.L. Hazen, S.J. Bograd, P.I. Miller, R.D. Andrews, A.N. Zerbini, and E.A. Falcone. (2017). Should I stay or should I go? Modelling year-round habitat suitability and drivers of residency for fin whales in the California Current. *Diversity and Distributions* 23 (10), 1204-1215. https://doi.org/10.1111/ddi.12611.

Schomer, P.D., J. Erdreich, P.K. Pamidighantam, and J.H. Boyle. (2015). A theory to explain some physiological effects of the infrasonic emissions at some wind farm sites. *J Acoust Soc Am.* 137(3):1356-65. https://doi.org/10.1121/1.4913775

Seminoff, J.A., C.D. Allen, G.H. Balazs, P.H. Dutton, T. Eguchi, H.L. Haas, S.A. Hargrove, M.P. Jensen, D.L. Klemm, A.M. Lauritsen, S.L. MacPherson, P. Opay, E.E. Possardt, S.L. Pultz, E.E. Seney, K.S. Van Houtan, R.S. Waples. (2015). Status Review of the Green Turtle (Chelonia mydas) Under the U.S. Endangered Species Act. NOAA Technical Memorandum, NOAANMFS-SWFSC-539. 571pp.

Soldevilla, M., K. Ternus, A. Cook, J.A. Hildebrand, K.E. Frasier, A. Martinez, and L.P. Garrison. (2022). "Acoustic localization, validation, and characterization of Rice's whale calls", The Journal of the Acoustical Society of America 151, 4264-4278 https://doi.org/10.1121/10.0011677.

Solick, D.I. and C.M. Newman. (2021). Oceanic records of North American bats and implications for offshore wind energy development in the United States. *Ecology and Evolution*, 11(21):14433-14447.

Sorte, F.A.L. and Fink, D. (2017). Projected changes in prevailing winds for transatlantic migratory birds under global warming. *Journal of Animal Ecology*, vol. 86, pp. 273–284.

Sparrow, B.D., W. Edwards, S.E. Munroe, G.M. Wardle, G.R. Guerin, J.F. Bastin, B. Morris, R. Christensen, S. Phinn, and A.J. Lowe. (2020). Effective ecosystem monitoring requires a multi-scaled approach. *Biological Reviews*, vol. 95, pp. 1706-1719.

Spalding, M., H. Fox, N. Davidson, Z. Ferdana, M. Finlayson, B. Halpern, M. Jorge, A. Lombana, S. Lourie, K. Martin, E. McManus, J. Molnar, K. Newman, C. Recchia, and J. Robertson. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience, vol. 57 (7):573-583.

Speich, S. M. and T.R. Wahl. (1989). Catalog of Washington seabird colonies. U.S. Fish and Wildlife Service Biological Rep. 88(6). 510 pp. Washington, D.C.

Spies, R. B., Senner, S., & Robbins, C. S. (2016). An overview of the northern Gulf of Mexico ecosystem. *Gulf of Mexico Science*, *33*(1), 9.

Sullivan, M.C., R.K. Cowen, and B.P. Steves. (2005). Evidence for atmosphere–ocean forcing of yellowtail flounder (Limanda ferruginea) recruitment in the Middle Atlantic Bight. Fisheries Oceanography, 14: 386-399. https://doi.org/10.1111/j.1365-2419.2005.00343.x

Switzer, M., D. Townsend, N. Pettigrew. (2020). The effects of source water masses and internal recycling on concentrations of dissolved inorganic nutrients in the Gulf of Maine. *Continental Shelf Res. 204:104157.*

Taylor, BL., K.K. Martien, F.I Archer, K. Audley, J. Calambokidis, T. Cheeseman, J. De Weerdt, A. F. Jordán, P. Martínez-Loustalot, C.D. Ortega-Ortiz, E.M. Patterson, N. Ransome, P. Ruvelas, J. U. Ramírez. (2021). Evaluation of humpback whales wintering in Central America and southern Mexico as a demographically independent population. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-655. https://doi.org/10.25923/sgek-1937.

Thurber, A.R., A.K. Sweetman, B.E. Narayanaswamy, D.O.B. Jones, J. Ingels, and R.L. Hansman. (2014). Ecosystem function and services provided by the deep sea, *Biogeosciences* 11:941-3963. https://doi.org/10.5194/bg-11-3941-2014

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H., and P. Rasmussen. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena*, (L.)). *Journal of the Acoustical Society of America*, vol. 126, pp. 11-14.

Townsend, D.W., N.D. Rebuck, M.A. Thomas, L. Karp-Boss, and R. M. Gettings. (2010). A changing nutrient regime in the Gulf of Maine. *Continental Shelf Res.* 30: 820-832

Trice, A., C. Robbins, N. Philip, and M. Rumsey. (2021). *Challenges and Opportunities for Ocean Data to Advance Conservation and Management*, Ocean Conservancy, Washington D.C. https://oceanconservancy.org/wp-content/uploads/2021/05/Ocean-Data-Report-FINAL.pdf.

Tynan, C. T., D. G. Ainley, J. A. Barth, T. J. Cowles, S. D. Pierce, and L. B. Spear. (2005). Cetacean distributions relative to ocean processes in the northern California Current System. Deep Sea Research Part II: Topical Studies in Oceanography 52:145-167. https://doi.org/10.1016/j.dsr2.2004.09.024.

United States Carbon Cycle Science Program. North American Continental Margins : a Synthesis and Planning Workshop : Report of the North American Continental Margins Working Group for the U.S. Carbon Cycle Scientific Steering Group and Interagency Working Group, report, 2008; Washington D.C.. (https://digital.library.unt.edu/ark:/67531/metadc949547/: accessed May 5, 2022), University of North Texas Libraries, UNT Digital Library, https://digital.library.unt.edu - UNT Libraries Government Documents Department.

U.S. Fish and Wildlife Service. (1996). Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley Massachusetts. 258 pp. http://omnilearn.net/esacourse/pdfs/piping_plover_recovery_plan96.pdf.

U.S. Fish and Wildlife Service. (2005). Regional Seabird Conservation Plan, Pacific Region. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, Portland, Oregon

U.S. Fish and Wildlife Service. (2021). *Birds of Conservation Concern 2021*. United States Department of the Interior, U.S. Fish and Wildlife Service, Migratory Birds, Falls Church, Virginia. http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php.

Valverde, R. A., and Holzwart, K. R. (2017). Sea turtles of the Gulf of Mexico. In *Habitats and biota of the Gulf of Mexico: before the Deepwater Horizon oil spill* (pp. 1189-1351). Springer, New York, NY.

Van Cleve F.B., C. Judd, A. Radil, J. Ahmann, and S.H. Geerlofs. (2013). Geospatial Analysis of Technical and Economic Suitability for Renewable Ocean Energy Development on Washington's Outer Coast. Pacific Northwest National Laboratory, prepared for Washington State Dept. of Natural Resources. (No. PNNL-22554). Pacific Northwest National Laboratory. http://www.msp.wa.gov/wpcontent/uploads/2013/07/PNNL_EnergySuitability_Final-Report.pdf.

Van Parijs SM, K. Baker, J. Carduner, J. Daly, G.E. Davis, C. Esch, S. Guan, A. Scholik-Schlomer, N.B. Sisson, and E. Staaterman. (2021). NOAA and BOEM Minimum Recommendations for Use of Passive AcousticListening Systems in Offshore Wind Energy Development Monitoring and Mitigation Programs. Front. Mar. Sci. 8:760840.

Vanhellemont, Q., and Ruddick, K., (2014). Turbid wakes associated with offshore wind turbines observed with Landsat 8, Remote Sensing of Environment, Volume 145, (Pp. 105-115) https://doi.org/10.1016/j.rse.2014.01.009.

Walton, M.A.L., L.M. Staisch, T. Dura, J.K. Pearl, B. Sherrod, J. Gomberg, S. Engelhart, A. Trehu, J. Watt, J. Perkins, R.C. Witter, N. Bartlow, C. Goldfinger, H. Kelsey, A.E. Morey, V.J. Sahakian, H. Tobin, K. Wang, R. Wells, and Erin Wirth. (2021). Toward an integrative geological and geophysical view of Cascadia subduction zone earthquakes. *Annual Review of Earth and Planetary Sciences*, 49.pp. 367-398

Ware, D.M. and R.E. Thomson. (2005). Bottom-up ecosystem trophic dynamics determine fish production in the Northeast Pacific. *Science* 308(5726):1280-1284.

Weber, E.D., T.D. Auth, S. Baumann-Pickering, T.R. Baumgartner, E.P. Bjorkstedt, S.J. Bograd, B.J. Burke, J.L. Cadena-Ramirez, E.A. Daly, M. de la Cruz, H. Dewar, J.C. Field, J.L. Fisher, A. Giddings, R. Goericke, El Gomez-Ocampo, J. Gomez-Valdez, E. L. Hazen, J. Hildebrand, C.A. Horton, K.C. Jacobson, M.G. Jacox, J. Jahncke, M. Kahru, R.M. Kudela, B.E. Lavaniegos, A. Liesing, S.R. Melin, L.E. Miranda-Bojorquez, C.A. Morgan, C.F. Nickels, R.A. Orben, J.M. Porquez, E.J. Portner, R.R. Robertson, D.L. Rudnick, K.M. Sakuma, J.A. Santora, I.D. Schroeder, O.E. Snodgrass, W.J. Sydeman, A.R. Thompson, S.A. Thompson, J.S. Trickey, J. Villegas-Mendoza, P.Warzybok, W. Watson, and S.M. Zerman. (2021). State of the California Current 2019-2020: Back to the Future With Marine Heatwaves? *Front. Mar. Sci.* 10(8).

West, S., R. Beilin, and H Wagenaar. (2019). Introducing a practice perspective on monitoring for adaptive management. *People and Nature*, vol. 1, pp.387-405.

Whitt, A., J.A. Powell, A.G. Richardson, and J.R. Bosyk. (2015). Abundance and distribution of marine mammals in nearshore waters off New Jersey, USA. Journal of Cetacean Research and Management.

Williams, R., C. Erbe, E. Ashe, A. Beerman, and J. Smith. (2014). Severity of killer whale behavioral responses to ship noise: a dose-response study. *Mar. Pollut. Bull.* 79 (1-2):254-260. https://doi.org/10.1016/j.marpolbul.2013.12.004.

Xiu, P., F. Chai, E.N. Curchitser. (2018). Future changes in coastal upwelling ecosystems with global warming: The case of the California Current System. *Sci Rep* **8,** 2866. https://doi.org/10.1038/s41598-018-21247-7.

Zwart, M.C., P. Robson, S. Rankin, M.J. Whittingham, and P.J. McGowan. (2015). Using environmental impact assessment and post-construction monitoring data to inform wind energy developments. *Ecosphere*, vol. 6, pp. 1-11.

Appendix: Monitoring tools and techniques

There is a broad array of available tools and techniques to support monitoring for offshore wind energy development. This section briefly describes each data collection method referred to in Chapter 3 (general and regional monitoring priorities), including the taxa or habitats each is best suited for, the appropriate spatial scale of data collection (local, sub-regional, regional), the appropriate timeframe of data collection relative to offshore wind energy development (pre-, during, post-construction).

This chapter is not intended to be a complete guide to monitoring methods and it is vital that scientists and other relevant experts are deeply engaged in the design of any monitoring plan to ensure that data is collected in a statistically meaningful manner.[214] The monitoring should be informed by scientific methodology that is suitable for accurate analysis, be it by hypotheses or *post hoc* driven questions. Advantage should be taken of any opportunity where data can be collected on multiple priority taxa or indicators of ecosystem condition through a single data collection method. Dissolving the boundaries between taxa-specific monitoring studies is fundamental to EBM and will also result in a greater return on investment.

Table A Monitoring tools and techniques

Tool/technique	Description	Taxa	Scale	Timeframe
Seabed sampling	Samples the sediment by either a Remotely Operated Vehicle or professional SCUBA divers at depths up to 40 meters. Used to identify the bottom type as well as the benthic species present. Provides a snapshot of conditions at the time of the sample. Time series data can be used to monitor changes in benthic species occurrence and distribution over time.	Benthic species	Sub-regional, Regional	Pre-construction baseline, post-construction
Underwater Video Monitoring	Mounted underwater cameras, either baited of unbaited. Provides non-invasive presence and behavioral information (e.g. foraging) regarding site usage by local species. Time series can be used to monitor species interactions with offshore wind infrastructure (e.g. if they serve as aggregating devices).	Fish, invertebrates	Local	Post-construction

[214] We refer readers to the NYSERDA State of the Science Workgroup Reports for more information and examples of monitoring tools and techniques.

Tool/technique	Description	Taxa	Scale	Timeframe
Acoustic backscatter	An acoustic device is used to produce sound and monitor resulting echoes. Data collected provides information about species presence, distributions and population densities. It is possible to identify large aggregations of zooplankton or fish. Time series data can provide insights into how zooplankton and fish occurrence and distribution may change over time.	Fish, Zooplankton	Sub-regional, Local	Pre-construction baseline, post-construction.
Vessel-based visual surveys	Observers are located on a vessel undertaking a standardized transect survey or off-track focal follows, depending on the research question. Can provide data on species presence, abundance, and distribution. Time series data can be used to detect changes in occurrence, distribution and habitat use. Distance sampling can be used to develop species density estimates for some taxa. Vessel-based visual surveys have more limited survey areas than digital or personned aerial surveys but relatively higher rates of species identification depending on the taxa, and can be used to observe behavioral states (e.g., foraging). Note that bird identification can be lower than other methods, and the presence of vessels can add a detection bias by scaring away birds.	Small and large cetaceans, Sea turtles, Birds	Regional, Sub-regional, Local	Pre-construction baseline, during construction, post-construction.
Personned aerial surveys	Planes fly at low altitudes and trained spotters record sightings of marine mammals and other taxa. Time series data on species presence can be used to detect changes in distribution and habitat use. Distance sampling can be used to develop density estimates for some species. Spotters can also record information on behavior (e.g., foraging, migrating, socializing). Distance sampling is the most common method, and this can be modified to include off-track focal follows. Personned aerial surveys have a higher rate of detection for large whales than digital aerial surveys, but species identification is more limited for small	Large cetaceans, Sea turtles, Birds, Large fish, Prey balls	Regional, Sub-regional, Local	Pre-construction baseline, during construction, post-construction.

Tool/technique	Description	Taxa	Scale	Timeframe
	cetaceans, sea turtles, and large fish. Surveys aimed at monitoring whales are at a high altitude that is not feasible for bird detection and identification. Personned aerial surveys need to be calibrated to fly at heights greater than the height of the turbines once constructed.			
Digital aerial surveys	Functions similar to a personned aerial survey (above), but a camera is used instead of a spotter. The photos are saved to a database and then later used for species identification. Time series data can detect changes in occurrence, distribution, and habitat use. Distance sampling can be used to develop species density estimates. This method has a higher rate of detection and species-level identification for birds, sea turtles, and some fish than personned aerial surveys. However, the limited strip width, lack of real-time ability to observe behaviors (e.g., whale blow, diving), and inability to undertake off-track focal follows mean that detection of large whales is more limited. Avian detection works best with large bodied seabirds that are easily distinguished from each other. Data also requires lengthy post-processing necessary to access results	Small cetaceans, Sea turtles, Birds, Large fish, Prey balls	Regional, Sub-regional, Local	Pre-construction baseline, during construction, post-construction.
Infrared monitoring (aerial)	Infrared cameras installed on unmanned aircraft systems provides nocturnal flight information. Useful for identifying presence on site, as well as collision risk models. Monitoring for extended periods of time can provide the necessary information to build an array of time series capable of detecting changes in occurrence, distribution, and habitat use.	Birds, Bats	Local	Pre-construction baseline, post-construction.
Infrared monitoring (vessel-based)	Infrared cameras used by trained observers on vessels can facilitate the detection of cetaceans during darkness. The effectiveness of this technology is still being tested for several species. Results to date indicate it is an effective complementary	Cetaceans	Local	During construction

Tool/technique	Description	Taxa	Scale	Timeframe
	monitoring method even during daylight. However, effectiveness is limited during poor weather conditions (rain, fog, etc.). This serves as a technological support for manned observations during vessel-based surveys. Its primary purpose is to support mitigation protocols.			
Satellite telemetry	Satellite tags are attached to individuals within a population and collect and store geo-spatial information about the individual's movements. For marine animals, they require the individuals to spend time at the surface so the tags can obtain coordinates from the satellite. There are a range of tag types developed, from short-term suction tags to long-term deep-implant tags; the latter may require permits and their use may be restricted for endangered species. Some tags require removal from the individual for data retrieval. It is important to note that usage is limited to life of battery or attachment to the animal. May range from hours to months depending on tag type. Satellite tags can and should be combined with other types of sensors, including pressure sensors that detect dive depth for in-water species, altimeters to show flight altitudes of birds and bats (a critical piece of information in determining risks from offshore wind energy developments), and acoustic and environmental sensors. Together, these data streams are useful for developing longer term models of populations movements and behaviors.	Small and large cetaceans, surface oriented fish, bats, Sea turtles, Birds (excluding passerines, smaller tubenoses such as storm petrels, and smaller-bodied shorebirds like piping plover and phalaropes	Regional, Sub-regional, Local	Pre-construction baseline, during construction, post-construction.
Radio telemetry	A radio transmitter is secured to the individual's body. It transmits a radio signal that is received by an antenna and radio receiver that are placed offshore. Unlike other methods of radio telemetric work, this is automated. Multiple radio receivers are	Marine mammals with site	Regional, Sub-regional, Local	Pre-construction baseline, post-construction.

Tool/technique	Description	Taxa	Scale	Timeframe
	needed to properly triangulate the individual. In addition to insights about individual habitat usage offshore (e.g., migratory movements for birds and bats), it offers a way to estimate density and detect patterns in species presence and usage across a given area.	fidelity, Birds, Bats		
Acoustic telemetry	Acoustic devices are implanted in the body cavity of a fish or secured to the outer shell of a turtle. The fish or turtle is released back into the ecosystem, and the device pings off acoustic receivers. Multiple acoustic receivers are needed if one seeks to triangulate the individual. The usage of these tags is dependent on lifespan of the fish or turtle and the transmitter battery. Current technology for fish acoustic telemetry can range from months to years based on transmitter size and activity settings.	Sea turtles, Fish	Regional, Sub-regional	Pre-construction baseline, post-construction.
Water turbulence	The most common method of measuring ocean turbulence is to use velocimeters to measure the flow of water. Some academic work has been done using velocimeters paired with temperature readings to build a fuller model of the turbulence changes. Depending on the situation, these sensors have been suspended in water using oceanographic moorings. Since turbulence effects from offshore wind energy are still being understood, it is recommended that water turbulence monitors be paired with other monitoring efforts that require oceanographic mooring. Applications range from detecting immediate oceanographic changes around one turbine or site to monitoring long-term oceanographic changes that may result from cumulative commercial build out of offshore wind energy.	Ecosystem	Local, Regional	Pre-construction baseline, post-construction.

Tool/technique	Description	Taxa	Scale	Timeframe
Archival passive acoustic monitoring (below water)	Hydrophones are placed in the water to capture sound readings from the broader ocean environment. The technique can provide broad insight into the soundscape of the regional marine environment through long term monitoring of ambient noise levels or can be used to detect the presence of specific species (e.g., baleen whale calls). Passive acoustic monitoring systems can maintain continuous recordings for several weeks up to multiple years. Analysis requires data retrieval from the hydrophone.	Large and small cetaceans, Broader ecosystem	Regional, Sub-regional, Local	Pre-construction baseline, during construction, post-construction.
Marine radar	Used to detect the vertical profiles of animals in flight and allows for large scale tracking of their movements across regions. Requires either the use of existing weather radar systems or the installation of more specific radar technology designed for wildlife monitoring. Specialized technology provides more detailed information, but weather radar is already broadly implemented.	Birds, Bats	Regional	Pre-construction baseline, during construction, post-construction.
Collision detection	Using a collision sensor affixed to each of the blades, it is possible to monitor for bird or bat collisions that might otherwise go unobserved. The most effective collision detection technologies are multi-model sensors pair an inertial monitor with a contact microphone as well as a micro camera that, once triggered by a collision event, will provide video from before and after the collision. These technologies are largely still in development, but in theory, receivers can be installed for the lifetime of the offshore wind energy project.	Birds, Bats	Local	Post-construction.
Acoustic receivers	Acoustic receivers that are designed to recognize and capture bat calls at frequencies outside of human hearing and translate them into recognized audio signals. Sound interference from wind turbines can be mitigated by choosing microphones with	Birds, Bats	Local	Post-construction.

Tool/technique	Description	Taxa	Scale	Timeframe
	shielding or that are not omnidirectional. Receivers can be installed for the lifetime of the offshore wind energy project (however, the system requires upkeep for battery life and data retrieval). While used for birds as well as bats, they do not capture species who might not vocalize (e.g., during migration) and do not estimate flux. They should be used in conjunction with other methods to address this.			