Frequently Asked Questions: Offshore Wind and Whales

May 2025

Final Version (Version 5.0)

Developed by the Whale Communications Specialist Committee of the Environmental Technical Working Group, with support from the Biodiversity Research Institute

Introduction

The Environmental Technical Working Group (E-TWG) is an independent advisory body to the State of New York, formed in 2017, with a regional focus on offshore wind and wildlife issues from Maine to North Carolina. It is comprised of offshore wind developers, science-based environmental non-government organizations, and state and federal wildlife agencies. The E-TWG undertakes activities such as the development of best management practices and identification of research needs regarding wildlife. With direction from the E-TWG and the New York State Energy Research and Development Authority (NYSERDA), topically focused Specialist Committees (SCs) bring together science-based subject matter expertise to develop specific products and recommendations that inform or advance the environmentally responsible development of offshore wind energy. Specialist Committees include both E-TWG and non-E-TWG members from a range of backgrounds, as appropriate for each committee's charge.

The Whale Communications Specialist Committee was formed in May 2023 to develop communications materials to aid in the dissemination of current, accurate, and readily understandable information around whale mortality events[1] and the level of potential risk to whales from offshore wind energy development activities. The Specialist Committee included representatives from environmental nonprofit organizations, state agencies, and offshore wind energy developers, and received scientific support from the Biodiversity Research Institute and facilitation support from the Consensus Building Institute. External reviewers of Committee products encompassed a number of scientific experts including federal and state agency representatives, academics, and other environmental stakeholders.

The main outcome of the Committee was this Frequently Asked Questions (FAQs) document, which groups topics into overarching themes and aims to provide two to three levels of information in response to each FAQ: 1) Brief bulleted summary; 2) Broad Answer: brief answer to key question (when necessary); and 3) Detailed Answer: Extended answer with associated scientific citations to provide readers with a better understanding of the facts and information sources. In addition to scientific citations, FAQ responses in many cases have a "for more information" section that refers the reader to other materials aimed at a general audience, including web pages, videos, and popular media. The FAQ responses may also include discussion of other marine mammals besides large whales, and/or other anthropogenic activities besides offshore wind energy development, to provide detail and context.

The FAQ is intended primarily as a resource for stakeholders who are in direct communication with the general public, and who regularly receive questions from the public on these topics. The intent of this document is to provide scientifically sound, accurate answers, in varying levels of detail, to address common questions. End users should feel free to use or adapt the information in the FAQ as they see fit.

This document has been through multiple rounds of review by Specialist Committee members, E-TWG members, and external reviewers. If readers have comments on the FAQ, please reach out to Julia Gulka at julia.gulka@briwildlife.org.

Suggested Citation:
Whale Communications Specialist Committee. 2025. Frequently Asked Questions: Offshore Wind and Whales, Version 5. Report to the Offshore Wind Environmental Technical Working Group. 149 pp. Available at www.nyetwg.com/specialist-committees/wildlife-faqs/whale-communications.

Contents

Anthropogenic Impacts on Whales

How is climate change affecting large whales?

- Climate change is a global phenomenon that is causing changes in ocean currents, temperature, and chemistry. This can affect marine species in a variety of ways, including through changes in their distribution and health, as well as changes to the structure of marine food webs.
- Climate change may impact the location, timing (phenology), and abundance of lower trophic level organisms (e.g., planktonic algae, zooplankton) which fishes, birds, marine mammals, and other species eat. This may particularly affect large whales that require substantial quantities of food for survival and reproduction. To date, most known impacts to marine mammals from changing environmental conditions are due to changes in the relationships between predators and prey.
- Climate change may also have secondary consequences for marine mammals, including impacts to their migratory patterns, energetic reserves, and stress levels. If these impacts are severe, population level consequences could occur.

Detailed Answer

Climate change is a global phenomenon that is altering ocean temperatures and large- and small-scale ocean patterns (Doney et al. 2012). Impacts of climate change to ocean environments also include changes to the chemistry and physics of seawater (Simmer et al. 2023). These changes have consequences for marine life from small planktonic organisms (Barton et al. 2016, Heneghan et al. 2023) to large whales (Record et al. 2019, Meyer-Gutbrod et al. 2021). There is a direct relationship between terrestrial, atmospheric, and oceanic temperatures, so atmospheric warming results in warmer surface ocean temperatures, which are then circulated deep into the ocean, increasing the global ocean temperature (Huang et al. 2003). Ocean circulation may also change, including changes in the speed and/or the course of currents (Doney et al. 2012). If marine species are sensitive to ocean chemistry, temperature, and/or circulation, there could be direct consequences, such as altered species distributions (Meyer-Gutbrod et al. 2021, Thorne & Nye 2021), health declines (Bossart 2011, Durban et al. 2021), and changes to food web structure (Harley et al. 2006).

Most climate-change impacts to marine life, including large whales, are the result of altered food webs and effects on species that play key connecting roles. Most marine life, particularly lower trophic level species, such as plankton, are dependent on a relatively narrow set of environmental conditions that include sunlight penetrating through the ocean surface, temperature, salinity, chemistry, dissolved oxygen, and other factors. Small planktonic algae (photosynthetic organisms) are the basis of global ocean food webs and are particularly sensitive to the above components. Importantly, these microscopic organisms drift with ocean currents and are not capable of significant lateral movement. They can also increase rapidly in abundance under ideal conditions (on the scale of days to weeks). Planktonic algae are consumed by small animals called zooplankton, which are then consumed by larger marine species including fish, birds, jellyfish, and even whales. As a result, there are often seasonal fluctuations in plankton abundance that drive seasonal abundance of species at higher trophic levels. Climate change may impact the location, timing, and abundance of lower-trophic-level species in ocean ecosystems, as well as the timing and magnitude of seasonal abundance patterns, which may impact large marine species that require substantial quantities of food for survival and reproduction, including large whales.

Marine mammals globally and regionally are subjected to impacts from climate change (Gulland et al. 2022), from direct drivers, such as ocean temperatures, to indirect drivers, such as changes to the timing (phenology; e.g., Henderson et al. 2017) and location (distribution; e.g., Nye et al. 2009) of resources. As a result, any mismatch in the location and timing of whales and their prey could lead to changes in food web dynamics (Durant et al. 2007), and ultimately to shifts in the distributions of marine mammal populations (Record et al. 2019, Meyer-Gutbrod et al. 2021). To date, the most observed impacts to marine mammals from changing environmental conditions are due to changes in the relationships between predators and prey (Ramp et al. 2015, Meyer-Gutbrod et al. 2021, Thorne & Nye 2021, Gulland et al. 2022), which in turn can influence a number of behavioral and biological factors that could inform the scale and severity of climate change impacts on large whales (Figure 1).

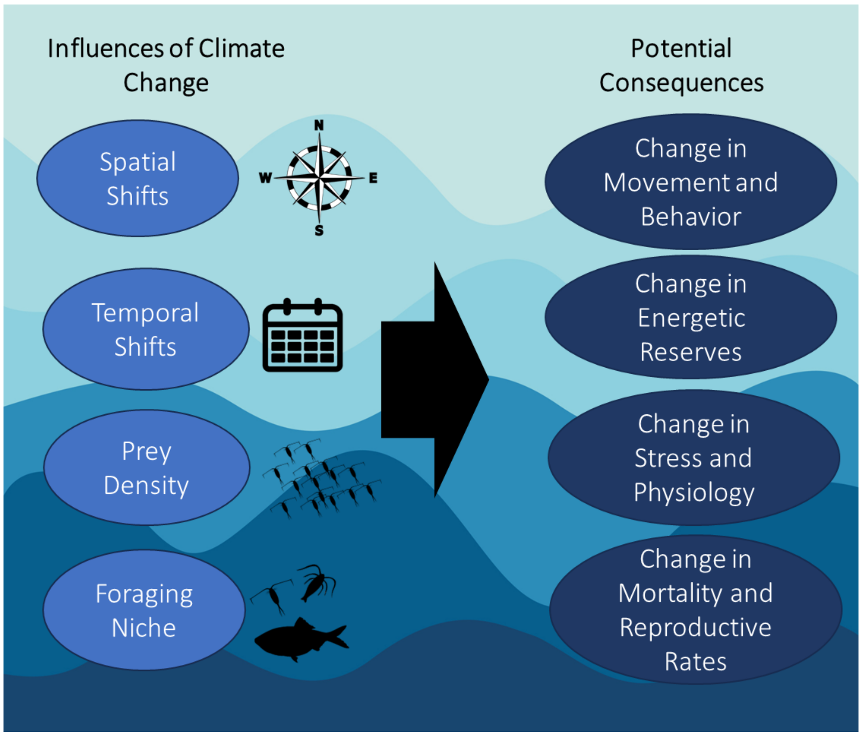

Figure 1. Potential ways in which climate change may alter food web dynamics for whales and the potential consequences of these changes on individuals and populations.

Changes to food webs include:

- Spatial changes – Documented climate impacts on species consumed by large whales include distribution shifts towards the poles (i.e., northward in the northern hemisphere—Perry et al. 2005, Nye et al. 2009, Stafford et al. 2022), shifts into deeper waters, which are typically cooler than surface waters (Pinsky et al. 2013, Thorne & Nye 2021), and shifts into previously unused regions. As a result, marine mammals have adjusted their distribution to follow prey (Meyer-Gutbrod et al. 2021), switched to alternative prey sources (Fleming et al. 2016), or expanded their range into northern regions while contracting their southern range (Hastings et al. 2020). The poleward movement of large whale distributions could be impacted by the available habitat for prey, as prey aggregations driven by cold, nutrient-dense water are paramount to their foraging success (Croll et al. 2005). Prey shifting into deeper waters could cause large whale predators to move farther offshore, exerting more energy to dive deep to forage. In addition, deeper prey could impede foraging success for some individuals, such as young animals, that are less efficient divers. Importantly, if whales are shifting their distribution, range, or prey preferences, there could be ramifications for anthropogenic risk: if whales begin to utilize highly urbanized regions, they may be at increased risk of vessel strike (see *What factors influence vessel strike risk for large whales?*). If whales shift their spatial distribution, existing spatial management practices may not be effective or cover these new areas, which has been demonstrated for North Atlantic right whales in eastern Canada (Davies & Brillant 2019). The recent northward shift in the distribution of prey for North Atlantic right whales led many whales to move out of the Gulf of Maine and into the Gulf of St. Lawrence. This led to increased whale mortality from vessel strikes and entanglements in fishing gear, as management practices were not yet in place for the species in this region (Moore et al. 2021).

- Prey Density Changes – The density of prey is a key factor for large whales, which rely on high densities of prey for foraging success (Van Der Hoop et al. 2019). Climate projections suggest that prey density may decrease under warmer ocean conditions, which could impact foraging efficiency and overall energetic reserves for large whales (Seyboth et al. 2016).
- Temporal changes – The timing of species migrations and movements has been impacted by climate change, and multiple large whale species have been documented arriving, reproducing, and residing earlier or later than normal in historical habitats. For example, the Gulf of Maine has undergone substantial warming in the last two decades (Saba et al. 2016, Pershing et al. 2021); as a result, the timing of "spring," as defined by the onset of key environmental parameters and biological abundance increases (similar to terrestrial spring), has started earlier than normal in recent years. In addition, "fall" has started later, which effectively increases the length of the summer season (Thomas et al. 2017, Henderson et al. 2017b, Staudinger et al. 2019). These changes to an ecosystem that is used by all large whale species found on the U.S. Atlantic coast could have ramifications for where and when large whales migrate. Highly migratory whales, such as humpback and North Atlantic right whales, may be particularly susceptible if climate change impacts affect their breeding and foraging habitats differently, or disproportionately (Staudinger et al. 2019, Pendleton et al. 2022). As a result of shifting environmental conditions, the timing of foraging and location of foraging habitat has shifted for large whales (Pendleton et al. 2022) and their prey (Henderson et al. 2017b). Importantly, some management measures to reduce anthropogenic risk to large whales are enacted during times of the year when their presence has been historically high (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*), but as the timing of these patterns shift, there may be additional risk from human impacts and management measures may need to be updated to remain effective (Pendleton et al. 2022, Stepanuk et al. 2023).
- Foraging niche – Some whale species (e.g., humpback, gray, and beluga whales) have a relatively flexible diet and are able to more readily switch between different prey species based on availability (Smith et al. 2015, Fleming et al. 2016). Other species (e.g., North Atlantic right whales) are highly dependent on one or a few prey species and, therefore, are highly sensitive to changes in those prey (Sorochan et al. 2019). For flexible foragers, some have shifted between different prey types based on varying ocean conditions (Fleming et al. 2016). The ability to switch between species may be beneficial if prey undergo distribution shifts or changes in abundance due to climate change, as the flexible whale species will be better able to compensate by consuming a different species. However, this may result in the consumption of lower-quality prey, reducing body condition and energetic stores (Choy et al. 2020). Shifts in prey could also lead to changing whale distributions, which may lead to increased conflict with human activities (e.g., vessel traffic; Thorne & Wiley 2024). For species that are tightly linked to specific prey (such as the North Atlantic right whale with *Calanus* copepod species), climate-driven changes to the distribution of prey may have substantial impacts on the large whale predators (see "spatial changes," above).

In addition to changes in populations of whale prey and in predator-prey dynamics, climate change has the potential to affect whale behavior and biology more directly. Whales are warm-blooded and are therefore able to regulate their internal temperature. As a result, they are likely able to adjust to the direct impacts of ocean temperature increases. However, there are a number of behavioral and biological factors that influence the scale and severity of climate change impacts for large whales:

- Annual migratory patterns – Some marine mammal species, such as humpback and North Atlantic right whales, are highly migratory, undergoing large-scale seasonal movements between high-latitude foraging habitats and lower-latitude breeding habitats. In the Northwest Atlantic region, foraging grounds are located off the northeastern coast of the U.S., throughout eastern Canada, and northward; calving grounds are in the southeast U.S. (for North Atlantic right whales), and in the Caribbean (for humpback whales). Other large whale species, such as fin and sei whales, may also undergo migrations, but the nature of these migrations is not well understood. However, humpback and North Atlantic right whales rely on warm, calm waters for calving, where they mostly forego foraging. Most of their food consumption occurs during warmer months on the foraging grounds. Foraging and breeding success are dependent on sufficient environmental conditions in all habitats, and climate-driven changes to the timing or location of environmental conditions could impact populations of large whales. Variations in environmental conditions, such as sea surface temperature and sea ice availability, have driven the earlier arrival of fin whales to the Gulf of St. Lawrence by two weeks (Ramp et al. 2015), and blue whales have been documented arriving one month earlier than previously known in California (Szesciorka et al. 2020). Off the northeastern U.S., North Atlantic right, fin, and humpback whales demonstrated earlier peak foraging habitat use by more than two weeks compared to the timing of habitat use 20 years prior (Pendleton et al. 2022). Habitat use in the mid-Atlantic region is also becoming extended for North Atlantic right whales, meaning that the migratory pulse in right whale presence that was historically observed is now less clear (Hodge et al. 2015, Davis et al. 2017). On the calving grounds, there could be climate-driven consequences if changes to the direction and speed of currents conflicts with migration patterns, or if local current speeds make for inhospitable environments for young calves, which rely on calm, warm waters close to shore (von Hammerstein et al. 2022).
- Energetic reserves – For migratory whales, such as humpback and North Atlantic right whales, energy stores are primarily accumulated during intense foraging efforts in the warmer months, and energy is spent during breeding and reproduction in winter months. Migration is also an energetically expensive behavior, and migratory species rely on stored energetic reserves (e.g., blubber) for part of each year. Impacts of climate change on energetic reserves could result from decreased foraging success, as variability in whale body condition is directly related to variability in foraging success (Vermeulen et al. 2023).
- Stress and physiology – Marine mammals can demonstrate stress through elevated hormone levels. Historical analyses of fin, humpback, and blue whale hormones indicate a relationship between elevated stress hormones and industrial whaling efforts (Trumble et al. 2018), suggesting that major events with population-level consequences can be detected through stress levels. Importantly, some research suggests that distribution shifts due to climate change may make marine mammals more susceptible to stressful anthropogenic impacts (Davies & Brillant 2019), such as those from vessel traffic and noise (Lemos et al. 2022, Pallin et al. 2022). Stress resulting from anthropogenic impacts combined with stress due to prey changes, reproduction, toxin exposure, and migration, can ultimately impact body condition and individual health (Hunt et al. 2013).

Are whale and prey distributions changing? If so, why?

- There is evidence that whale distributions are changing in the Northwest Atlantic marine ecosystem. Many species are shifting their feeding areas in response to oceanographic changes, including changes in temperature, currents, and stratification (see *How is climate change affecting large whales*?), though the degree and direction of change is species- and season-specific.
- Humpback, minke, and sei whale distributions are generally shifting north, and North Atlantic right whales are spending more time in the Gulf of Saint Lawrence, further offshore, and near canyon areas. There have also been shifts in the phenology (i.e., timing) of habitat use across species.
- Whales primarily eat schooling fishes (sometimes called "forage fishes") and zooplankton (such as copepods and shrimp-like crustaceans, called krill). Oceanography-driven prey movement is one of the mechanisms driving range shifts in whales. Copepods and many forage fish species have shown northeasterly distribution shifts and movement into deeper waters. The range of krill has retracted, with animals no longer occurring in the former southerly portions of their range.
- Shifting prey resources due to increasing oceanographic variability can lead whales to increase travel distances and/or change their diet, and can cause potential mismatches in the presence of whales and their prey. This has the potential to influence population dynamics (e.g., survival, reproduction).

Detailed Answer

In the face of multiple anthropogenic stressors, including climate change, there is scientific evidence that both whale and prey distributions are changing in the Northwest Atlantic marine ecosystem. The characteristics of these changes vary across species and regions, including shifting distributions in some cases north and into deeper waters and in others shifting south and inshore, contraction or expansion in range size, and changes in the timing of annual movements and habitat use (e.g., migration, foraging). One of the primary causes for many of these shifts is the change in distribution and biomass of prey, including zooplankton and forage fish, which in turn are influenced by temperature and other climate-induced changes in oceanography, such as changes in stratification and ocean circulation (Brickman et al. 2021). Increased interannual oceanographic variability has further caused a less predictable environment for whales and their prey.

Changes in Whale Distributions

There is substantial scientific evidence that the distributions of whales in the Northwest Atlantic have been shifting, with variation across species (Thorne & Nye 2021). In broad terms, species distributions are trending to the northeast along the continental shelf and into deeper waters (NOAA 2024), though these shifts are species specific. Baleen whales (e.g., humpback, minke, sei whales) are not shifting as dramatically as other marine mammal species, such as dolphins, based on analysis of aerial survey data (Chavez-Rosales et al. 2022). However, sei whales also have shown increased detections in the mid-Atlantic and more northern regions since 2010 (based on acoustic data; Davis et al. 2020). North Atlantic right whales ('right whales') have also demonstrated distribution shifts. Since 2010, North Atlantic right whales have spent less time in the Gulf of Maine and Bay of Fundy and more time in mid-Atlantic waters and the Gulf of St Lawrence (Davis et al. 2017, Davies et al. 2019). However, data from 2024 and early 2025 suggest that these new patterns may not remain constant, as many right whales were observed in the area around Hudson Canyon[1] and in the Gulf of Maine[2] during this period. This is likely related to oceanographic conditions that more closely resembled pre-2011 patterns, including the presence of colder, more productive waters that likely increased prey for right whales in the Gulf of Maine (Record et al. 2024). Humpback whales, more generalist feeders than right whales, have exhibited variable shifts by season in recent years, with a notable southerly shift into using the New York Bight as summer foraging habitat, as well as increased use of the Gulf of Maine (Thorne & Wiley 2024).

In addition to shifts in spatial distributions, there is also evidence that whales are changing the timing of their habitat use. A study examining phenological (e.g., timing) shifts in peak habitat use in Cape Cod Bay found that North Atlantic right whales and humpback whales shifted peak habitat use approximately 18–19 days later over the 20-year study period (Pendleton et al. 2022). Though shifts in fin whale peak habitat use were not observed in this study in Cape Cod Bay, similar shifts have been documented for fin and humpback whales in the Gulf of Saint Lawrence over a 27-year time span (1984–2010), with arrival dates >1 day earlier per year, and departure dates 0.4–1 day earlier for each year of study (Ramp et al. 2015).

Changes in Prey Distributions

In the North Atlantic, zooplankton (e.g., copepods, krill) form a major trophic link between primary producers and predators, including many fish and marine mammal species. Though there are multiple mechanisms driving the shifts in whale distribution, prey-related shifts are likely a key factor. The foraging strategies and diets of whales differ by species. North Atlantic right whales and sei whales are zooplanktivores (primarily eating copepods), while fin, humpback, and minke whales eat schooling fish, krill, and other prey and are considered generalists (Smith et al. 2015).[3] Foraging habits along with life history traits (e.g., migration distances, energetic needs) can influence the strength and direction of linkages between whale distributions and prey distributions. However, prey abundance can be difficult to measure at spatiotemporal scales relevant to whales, making it difficult for scientists to determine whether changes in whale habitat use are really being driven by changes in prey (Pendleton et al. 2022). Furthermore, some forage fish species, like Atlantic herring, menhaden, and mackerel, also support important regional commercial fisheries, and how these fisheries are managed is also a factor in the population status and local abundance of key prey species.

Despite these challenges and complex interactions, there is evidence of shifts in both zooplankton and forage fish distributions in the Northwest Atlantic marine ecosystem linked to climate-driven changes in oceanography, including temperature, currents, and stratification (Henderson et al. 2017a, NOAA 2024). Since 2008, the Gulf Stream has moved closer to Grand Banks, reducing the supply of cold water from the Labrador Current to the Gulf of Maine, in turn affecting temperature, salinity, and nutrient inputs in the region. The cold pool is a seasonal feature within the mid-Atlantic that influences suitability of habitat for many fish species. Since the mid-2000s, the cold pool has persisted for shorter portions of the year (NOAA 2024). Zooplankton distributions have likewise changed in recent decades. Data from 1968–2016 suggest that copepods have shifted their distributions to the northeast, with many fish and macroinvertebrate species showing a similar shift in distribution (Friedland et al. 2019). Interestingly, the same shift has not occurred for krill. As temperatures have increased, krill have been unable to shift north; rather, their range

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[1] New England Aquarium Press Release: https://www.neaq.org/about-us/press-room/press-releases/nearly-one-quarter-of-the-critically-endangered-north-atlantic-right-whale-population-spotted-in-an-unusual-feeding-area/

[2] New England Aquarium Press Release: https://www.neaq.org/about-us/press-room/press-releases/more-than-75-right-whales-sighted-off-the-coast-of-maine/

[3] NOAA Fact Sheets on Humpback Whales: https://www.fisheries.noaa.gov/species/humpback-whale; Minke Whales: https://www.fisheries.noaa.gov/species/minke-whale; Fin Whales: https://www.fisheries.noaa.gov/species/fin-whale

has reduced at the southern end of their range, with a 50% decline in surface krill abundance over the last 60 years (Edwards et al. 2021).

These differential responses to shifting oceanographic conditions directly influence both forage fish and whale distributions. For example, copepods are primary prey for North Atlantic right whales, and shifting distributions of right whales have largely been attributed to shifting resource availability in the Gulf of Maine and Gulf of St. Lawrence (Sorochan et al. 2019, Meyer-Gutbrod et al. 2023). NOAA's 2024 State of the Ecosystem report also indicates that stocks of 48 commercially or ecologically important fish species are shifting their distribution in both spring and fall, moving towards the northeast and into deeper waters throughout the Northeast U.S. Large Marine Ecosystem, with a stronger shift in the fall compared to spring (NOAA 2024). Changes in forage fish distributions will in turn affect the distribution of piscivores and generalists, such as humpback whales. In some cases, whales may shift distributions in response to changes in primary prey, while in other cases, shifting prey resources may result in prey switching. There is evidence that increased humpback whales in coastal waters of the New York Bight relates to a greater reliance on Atlantic menhaden as that stock has recovered from overfishing (Brown et al. 2018, Lomac-MacNair et al. 2022).

Potential Effects of Changing Distributions

For species, such as North Atlantic right whales, that have a relatively specialized or inflexible diet of copepods, shifting prey resources may lead directly to shifting distributions of whales to compensate. Dietary generalists, in contrast, may respond to shifting prey in various ways. For example, rather than shifting distributions, humpback whales may instead compensate by switching to different prey species. It is also possible, as in the case of pilot whales, that distributions of prey and whales can shift at different rates, suggesting a generalist foraging strategy that includes both shifting distributions to track prey as well as resource-switching (Thorne & Nye 2021). Shifting distributions have the potential to increase risk of anthropogenic impacts, particularly in cases where whales are shifting into areas without appropriate management regimes in place.

In addition to changes in the distribution of prey, there is also evidence that many prey are exhibiting changes in composition and energy content. In the case of invertebrates, the Mid-Atlantic has seen decreased body size of copepods and increasing abundance of gelatinous species that are less energy rich (NOAA 2024). For forage fish, the energy content of species like Atlantic herring, silver hake, and squid, have remained below energy content estimates from the 1980s and 1990s (NOAA 2024). Whales not only have to shift locations to follow prey but are also not gaining the same level of energy from prey as they have in the past, which has the potential to influence energetics and ultimately population dynamics (e.g., reproduction, survival). These changes have important implications for marine food web dynamics and ecosystem stability (Thorne & Nye 2021) as well as potential management implications for whales, such as increased interactions with vessels and relevance of existing protected areas. Quantifying the cause and extent of shifts in distributions is key for conservation strategies, particularly spatial management tools used to protect whales (e.g., transit lanes, slow zones; Davies et al. 2019). See *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*

What factors influence vessel strike risk for large whales?

- Vessel strikes are a major source of mortality and injury for large whales around the world.
- The chance of a vessel strike occurring depends on the co-occurrence or overlap of whales and vessels in space and time, with risk increasing as the densities of both ships and whales increase.

- Both the likelihood and severity of a vessel strike vary based on vessel characteristics (e.g., size, speed) and the behavior of the whale species involved.
- Vessel strike avoidance depends on the ability to detect a whale, and the time required for a vessel to enact a maneuver to avoid a whale. Thus, current efforts to reduce vessel strike risk in the U.S. depend on both relocating shipping lanes away from key whale habitat (i.e. reducing co-occurrence of whales and vessels) and implementing voluntary or mandatory speed restrictions in key areas. Reduced vessel speeds are known to reduce the severity of collisions and also likely reduce the probability of collisions by increasing reaction times and chances for whale detection by boaters.

Broad Answer

Vessel strikes are a primary source of mortality and serious injury for large whales around the world. The risk of a whale getting hit by a vessel is dependent on both whale behavior and vessel characteristics. The severity of vessel strikes varies based on multiple factors including the size, speed, type, and sound level of the vessel. For example, large vessels may be more immediately lethal to whales than small vessels, but any vessel operating at high speeds (e.g., greater than 10 knots or ~12 mph) poses a risk of injury or death to whales. In addition, the sound produced by a vessel may vary depending on vessel type, size, speed, and environment in which it travels (Erbe et al. 2019), which could impact whale behavior. Vessel strike risk also varies based on the behavior of whales. As vessels only operate in near-surface waters, behaviors conducted by a whale near the surface (e.g., feeding, sleeping, nursing) present the risk of vessel strike. Individual characteristics and activities of whales may influence the degree of this risk; for example, calves and juveniles spend more time at shallower depths, increasing their likelihood of interaction with a vessel. Whales may be more solitary or more aggregated based on sex, age, and foraging behavior, and the degree of aggregation behavior can influence risk. Whales feeding near the surface may be at higher risk of vessel strike, but this increased activity at the surface may also make them more detectable by boaters. Similarly, the longer a whale spends at the surface, the higher the chance it is detected by a boater. Ultimately, the risk of vessel strike is dependent on both vessel and whale characteristics that influence their degree of overlap in space and time and the ability of each to avoid the other. Current efforts to reduce vessel strike risk in the U.S. depend on (1) relocating shipping lanes away from areas of high whale density to reduce the overlap of whales and vessels, and (2) reducing vessel speed in areas and during times of importance for whales to reduce the severity of collision while increasing the ability for boaters to detect animals and conduct avoidance maneuvers.

Detailed Answer

Vessel strikes are a major source of mortality for large whales globally, and can lead to population-level impacts at a local scale (Clapham et al. 1999, Laist et al. 2001). Van der Hoop et al. (2013) examined mortality and serious injury for large whales in the Northwest Atlantic, and found that 67% resulted from human interactions, with entanglement in fishing gear and vessel strike as the primary causes. The risk of vessel strike depends on the specific characteristics of both the whale and the vessel. The occurrence of a vessel strike requires that both a whale and vessel co-exist in space and that the vessel protrudes into the portion of the water column where the whale is present. Therefore, vessel strike risk is higher in regions of high vessel traffic (Laist et al. 2001, Vanderlaan et al. 2009), and the probability of vessel strike within the water column is greater towards the ocean surface (Laist et al. 2001, Lammers et al. 2013). The risk and severity of a vessel strike (i.e., likelihood of severe injury or mortality) is influenced by vessel characteristics in the following ways:

- **Vessel Size** – Large vessels, such as cargo and shipping vessels, commonly have higher severity of lethality to large whales due to sheer size alone, but also pose high risk because they are more difficult to maneuver to avoid strikes (Laist et al. 2001). However, vessel strike risk posed by small vessels has been documented by the media[4], in the scientific literature, and federal technical reports (Henry et al. 2022). Documented whale deaths and serious injuries have occurred from small vessels, including whale-watching vessels, Coast Guard and Navy vessels, and ferries (Kelley et al. 2020). In addition, there is a higher risk of injury to operators and passengers onboard smaller vessels that collide with whales.

- Vessel Speed – Vessels traveling at high speed have a greater probability of lethality for large whales, as the blunt or sharp force trauma is more severe than that occurring at slower speeds (Conn & Silber 2013). In addition, like driving a vehicle on a highway, the reaction distance decreases with increased speed; thus, risk of strike (e.g., the inability to avoid) increases with speed. Vessel speed has been an important topic of scientific research, and restrictions on vessel speeds are a key management measure currently enacted in the U.S. In addition, although we know the probability of lethality is high for fast, large vessels, collisions with vessels of all sizes—from recreational boats to large ocean-going ships—are one of the primary causes of recent elevated North Atlantic right whale injuries and deaths.[5] Vessel strike is also a main source of mortality for sea turtles (Foley et al. 2019), with vessel speed significantly influencing the degree of risk (Hazel et al. 2007).
- Vessel Type and Sound Level – The type of vessel involved impacts the severity of vessel strikes. While both sailing and motorized vessels are capable of hitting whales at the surface, the risk of sharp force injury by propellors is much higher for motorized vessels. In addition, the sound produced by a sailing vessel may be dramatically different from that produced by a motorized vessel, as sound varies greatly depending on propeller characteristics, vessel size and speed, and even the environment in which a vessel is operating (Erbe et al. 2019). Though behavioral responses to noise could include increased vocalizations (Dahlheim & Castellote 2016), or even physical disruption through surfacing (Nowacek et al. 2004) or shallow dives (McKenna et al. 2015), there is no clear detection and response behavior elicited by whales broadly (Erbe et al. 2019). When considering the combination of vessel size, speed, and type, it is also important to consider vessel and operator behavior, which may lead to varying risk of vessel strike occurrence and severity. For example, a tug or tow vessel may operate in a straight line, at low speeds, while in proximity or while attached to a very large vessel and may therefore pose a relatively low vessel strike risk. In contrast, a fishing vessel may operate at high speeds, while passengers may be occupied with tasks that draw their eyes away from the water, and target areas where fish are known to congregate, which may also attract whales, and therefore lead to increased likelihood of interaction. Though vessel type and behavior are highly variable, these examples illustrate how different vessel types, speeds, sizes, and behaviors inform vessel strike risk.

The characteristics and behaviors of marine mammals may also influence the risk and severity of vessel strikes. The probability of a vessel strike occurring may vary based on species or individual behaviors. For example, vessel strikes are infrequently reported for dolphins as they are inherently nimble and can move rapidly to avoid being struck. In contrast, a large baleen whale is less capable of maneuvering quickly to avoid contact and has a greater surface area to strike. Individual behavior is also important, as vessel strike risk may be higher for individuals that are foraging or resting near the sea surface compared to those traveling at depths below the typical draft of vessels (Silber et al. 2010, Parks et al. 2012).

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[4] Whales in the media: https://www.the-scientist.com/news-opinion/why-did-this-whale-smack-into-a-boat-70267

[5] North Atlantic right whale Unusual Mortality Event: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2024-north-atlantic-right-whale-unusual-mortality-event

The overlap in space and time of large whale and vessel densities drives the risk of vessel strike (Laist et al. 2001, Vanderlaan et al. 2009), and is influenced in part by habitat use and behavior of the whales (Friedlaender et al. 2009, Parks et al. 2012, Blair et al. 2016, Stepanuk et al. 2021). For example, the coastal waters of the U.S. Atlantic coast tend to be areas where large whales are observed foraging, and also have dense vessel traffic, leading to high overlap in space and time. Changes in food and habitat due to climate change can also lead to an increase in overlap. For example, due to changing prey distributions, North Atlantic right whales shifted their distribution north into the Gulf of Saint Lawrence, resulting in increased vessel strikes (Davies & Brillant 2019). Variations in habitat use and foraging behavior within species and populations are based on a number of factors that influence the risk of vessels strike:

- Demographics – Age, sex, and reproductive status influence vessel strike risk (Craig et al. 2003, Whitehead & Rendell 2004, Teloni et al. 2008, Valsecchi et al. 2010). For example, while adult humpback whales forage in larger groups that are active at the sea surface (and therefore are easily detected by boaters), juvenile humpback whales tend to be more solitary and exhibit more erratic behaviors than older individuals (Clapham 1994, Stepanuk et al. 2021), making both detection and avoidance more difficult. In the case of North Atlantic right whales, pregnant females, female-calf pairs, and lactating females spend more time at, or near, the surface than other demographic groups (e.g., < 3.5m; Dombroski et al. 2021), increasing their risk of vessel strike (Baumgartner & Mate 2003, Dombroski et al. 2021). Distributions also may differ, with juvenile humpback whales showing greater preference for coastal habitats (which are generally areas with higher vessel traffic; Clapham 1994, Stepanuk et al. 2021), while adult whales are not regularly sighted in inshore waters. On the breeding grounds, documented vessel strikes of humpback whales have primarily involved calves and juveniles (Lammers et al. 2013), and humpback whale calves have been documented surfacing or residing at shallow depths and demonstrating high surfacing rates without their mothers (Lomac-MacNair et al. 2018). In addition to these behaviors that may increase risk for calves and juveniles, some researchers also hypothesize that vessel avoidance may be a learned behavior so young whales may not have as much knowledge or awareness of the need to avoid vessels (Laist et al. 2001, Panigada et al. 2006).
- Foraging behavior type – Some species vary their foraging behavior based on location, prey type, and/or time of day (Friedlaender et al. 2009, Blair et al. 2016). In the case of humpback whales, where subsurface foraging is regularly observed in the Stellwagen Bank region, whales are typically foraging near the sea floor on species like sandlance (Hain et al. 1995). In contrast, surface lunge feeding and coordinated bubble feeding are regularly observed in the waters of the New York Bight and Gulf of Maine (Stepanuk et al. 2021, Lomac-MacNair et al. 2022), presumably on schooling fish species (e.g., herring, mackerel, menhaden). North Atlantic right whales also employ different foraging strategies depending on prey type and location, utilizing surface or near-surface feeding, as well as feeding at depth (Baumgartner et al. 2017). Importantly, the near-bottom foraging behaviors may put whales at less risk of vessel strike compared to the surface foraging behaviors, as whales at depth are likely not within the range of the draft of a vessel. In addition, some whale species forage at the surface at night, but deeper in the water column during the day (Parks et al. 2012). As it is incredibly difficult to detect whales at the water's surface at night, this nocturnal near-surface feeding behavior may increase the risk of vessel strike.
- Surfacing behavior and morphology – There are multiple surface behaviors that may influence the level of risk of vessel strike. When whales breathe at the water's surface, their breath results in a visible blow that is more readily visible to boaters, with some individuals or species taking more breaths while surfacing. The number of possible cues at the surface is directly proportional

to how detectable the animal is by human observers (Gende et al. 2019) or by monitoring technologies like thermal imaging. Some species also rest (known as logging) and nurse at the surface, and the amount of time spent in these behaviors influences risk (Gende et al. 2019). In addition, the morphology of species and individuals influences surface detectability, and therefore risk of vessel strike. In particular, North Atlantic right whales lack a dorsal fin, which makes surface detectability more difficult than for other species.

Ultimately, factors that influence the risk of a vessel strike relate primarily to (a) overlap in vessel and whale activity, (b) the characteristics and behavior of vessels, and (c) the characteristics and behavior of whales. The probability of vessel strikes increases when the density of both vessels and whales is high, for example in areas of the New York Bight. Current efforts to reduce vessel strike risk in the U.S. include relocating shipping lanes away from key whale habitat (i.e. reducing co-occurrence of whales and vessels), as well as implementing voluntary or mandatory speed restrictions in key areas (i.e. reducing severity of collision while increasing reaction times and chances for whale detection by boaters; see *What mitigation measures are available to avoid and or minimize offshore wind effects on marine mammals?* for more information on vessel speed restrictions), and development and use of technologies, such as near-real-time passive acoustic devices, and placement of observers to help monitor for marine mammals in the vicinity in order to implement avoidance maneuvers.

What are the effects of anthropogenic sound on marine mammals?

- Increased levels of "background" sound, which can elevate the overall soundscape, can mask sounds produced by animals to communicate with each other and locate food, which can lead to changes in behavior and increased stress.
- The frequency ("pitch"), intensity ("volume"), and duration of sound influence whether an animal may be affected. Marine mammals have a range of hearing capabilities and thus may be affected by anthropogenic (human-caused) sound in different ways. Characteristics of individual animals (such as their age, life history status, behavioral state at time of exposure) can also influence their behavioral response to sound exposure.
- Discrete, loud sounds and longer-duration sounds can also potentially damage the hearing capabilities of marine mammals, either temporarily or permanently or cause non-auditory injury or even death.

Broad Answer

Sound is an important source of information produced and received by aquatic animals, especially since smell and sight are of less utility underwater than in terrestrial settings. Sound travels much farther and faster in water than in air, allowing animals to gather and transmit information over long distances. Thus, many aquatic animals rely heavily on sound for monitoring their surroundings, locating food, navigating, and communicating between individuals.

The frequency ("pitch") and intensity ("volume") of a sound influence whether an animal can hear it. These same factors, as well as the sound's duration, affect whether an animal may be affected by the sound. Marine mammal species have a range of hearing capabilities and thus may be affected by anthropogenic sounds in different ways. Individual factors, such as a marine mammal's age and sex, whether it has a dependent calf with it, behavioral state (e.g., feeding), and whether it has been exposed to similar sounds in the past, may also influence how they respond to sound exposure.

There are numerous sources of underwater sound in the ocean, some of which are natural (e.g., waves, other animals) and some of which are caused by human activities (e.g., vessel traffic, different types of sonar, etc.). Anthropogenic (human-caused) sound in the ocean can affect marine mammals in several ways, and human-caused sound has been increasing from sources such as vessel traffic. Increased levels of "background" noise, which elevate the overall volume of the soundscape underwater, can mask sounds that animals use to communicate with each other and locate food, making these activities more challenging. Increased background noise may also cause animals to alter their behavior, such as increasing the volume or changing the pitch of their own communication sounds.

Discrete, loud sounds can cause many of the same issues as increased background noise and also have the potential to damage marine mammals' hearing capabilities, either temporarily or permanently. This is similar to a person attending a very loud music concert that causes a temporary reduction in hearing acuity. Over time with repeated exposures, or if a single sound is loud and intense enough, such short-term tissue damage can become permanent.

Detailed Answer

Sound is an important source of information for aquatic animals, as other senses (e.g., smell, sight) are less useful underwater. Sound also travels much farther and faster in water than in air, allowing animals to gather and transmit information over long distances. All marine mammal species produce sound, which is associated with a variety of behaviors, including mating, raising young, social interactions, group cohesion, and feeding (Erbe et al. 2016).

There are numerous sources of underwater sound in the ocean, some of which are natural (e.g., waves, other animals) and some of which are caused by human activities (e.g., vessel traffic, different types of sonar). Natural sounds have been part of the ocean soundscape for millions of years, and as a result marine mammals have evolved to be acoustic specialists in this environment (Branstetter & Sills 2022). However, there has been a dramatic increase in anthropogenic noise since the industrial revolution (Duarte et al. 2021), including sound related to transportation, construction, military, and survey activities. Given this rapid increase in anthropogenic (human-caused) sound, marine species have not had the opportunity to evolve or adapt to this new environment.

Marine mammal species have a range of hearing capabilities and thus may be affected by anthropogenic sound sources in different ways. Marine mammals are classified into five groups based on the frequency of sounds they produce and hear underwater: (1) low frequency cetaceans (e.g., baleen whales), (2) high-frequency cetaceans (e.g., dolphins, toothed whales, beaked whales, bottlenose whales), (3) very high-frequency cetaceans (e.g., porpoises, river dolphins), (4) Phocid pinnipeds (e.g., true seals), and (5) Otariid pinnipeds (e.g., sea lions and fur seals). The National Oceanic and Atmospheric Administration (NOAA) has defined specific hearing frequency ranges for these groups (NMFS 2024b). The upper range of sounds audible to cetaceans (>20kHz) are in the so-called "ultrasonic" range and cannot be heard by humans.

In addition to species-specific hearing capabilities, the frequency ("pitch") of a sound and the sound's amplitude/intensity ("volume") influence whether an animal can hear it. These same factors, as well as the sound's duration, influence the degree to which an animal may be affected by the sound. Environmental factors (e.g., temperature, salinity, water depth, sediment characteristics) that influence sound transmission also play a role (Wartzok et al. 2003). Individual factors also influence whether a specific marine mammal responds to a sound. For example, a marine mammal's age and sex, whether it has a dependent calf with it, what behavior it is exhibiting at the time of sound exposure, its individual noise tolerance, and whether it has been exposed to similar sounds in the past, may all influence how it responds to sound (Wartzok et al. 2003, Ellison et al. 2012, Gomez et al. 2016). Anthropogenic sound in the ocean can affect marine mammals in several ways, including masking, behavioral changes, hearing loss, and strandings.

Masking

Masking occurs when sound (natural or anthropogenic) interferes with an animal's ability to perceive or produce important sounds (Erbe et al. 2016). Of all the ways that sound can affect the lives of marine mammals, auditory masking is likely the most pervasive (Hildebrand 2005). Increased levels of "background" noise, which raise the overall volume of the soundscape underwater, can mask sounds that animals use for various purposes, including to communicate with each other and locate food, making these activities more challenging or stressful. An analogous situation for humans is that it is much easier to effectively communicate in a quiet room compared with a busy street with cars honking and people yelling. There are multiple ways in which marine mammals may respond to auditory masking (often referred to as anti-masking strategies), including changing behavior, changing call rate, the Lombard effect (e.g., increasing the intensity of their vocalizations in the face of increased noise; Guazzo et al. 2020), changing the frequency range of their calls (Leroy et al. 2018), or relocating to quieter environments (Branstetter & Sills 2022). For example, blue whales have been shown to call more often when seismic devices were operating (Di Iorio & Clark 2009). Researchers have also demonstrated that North Atlantic right whales increase the amplitude of vocalizations in response to increased environmental sound levels (Parks et al. 2010). There is still a great deal of uncertainty regarding how masking affects marine mammals, in particular the degree to which masking may influence the energetic costs of changes in behavior or potentially increase stress levels, and thus potentially influence survival or reproductive success. Because of the widespread nature of anthropogenic activities, masking may be one of the most extensive and significant effects on acoustic communications for marine species and warrants additional research.

Behavioral Change

Exposure to anthropogenic sound can cause animals to alter their behavior, with the occurrence and significance of behavioral change varying by individual, species, and circumstances. Some sounds may not cause any response, while others could lead to changes in various behaviors, including diving, surfacing, vocalizing (see "masking," above), feeding, and mating.[6] Behavioral response depends on a number of factors, including an individual's hearing sensitivity, tolerance to noise, previous exposure to the same type of noise, the extent of repeated or cumulative noise exposure, behavior, and demographics (e.g., age, sex; National Research Council (U.S.) Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals 2003, Southall et al. 2019). Not all changes in behavior are of concern—some may be inconsequential (e.g., head turn), while other responses are within the range of natural variation. For example, one study found that humpback whales responded to increases in sound by increasing their average dive time and travel distance. However, these changes were well within the range of dive times and distances observed in the absence of anthropogenic sound (Frankel & Clark 2000), suggesting minimal negative consequences, although it was not possible to measure differences in foraging success in this study. Other changes in behavior have the potential to have detrimental effects, such as reduced feeding activity and avoidance of the affected area, which can have energetic consequences (Finley et al. 1990).

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[6] More on behavioral changes in mammals: https://dosits.org/animals/effects-of-sound/potential-effects-of-sound-on-marine-mammals/behavioral-changes-in-mammals/

Hearing Loss

Discrete loud sounds and longer-duration sound have the potential to damage the hearing capabilities of marine mammals, either temporarily or permanently.[7] This is similar to a person attending a very loud music concert that causes a temporary reduction in hearing acuity. Over time with repeated exposures, or if a single sound is loud and intense enough, such short-term tissue damage can become permanent. Hearing loss in marine mammals depends on many factors, including hearing sensitivity, intensity and frequency of the sound, and duration of exposure. Extremely loud, impulsive sounds (with high peak sound pressure, short duration, and fast rise times; NMFS 2024b) are more injurious at lower thresholds and can lead to temporary or permanent hearing impairment (Southall et al. 2019), but so too can longer periods of exposure to less intense or steady-state (e.g., non-impulsive) sound.

A hearing threshold is the minimum amplitude that an animal can hear at a given frequency. Sounds at certain intensity and duration above this threshold can cause changes to this threshold that are either temporary or permanent. If the threshold returns to normal after some period of time, the resulting impact is called temporary threshold shift (TTS). If the threshold does not return to normal levels, the effect is called permanent threshold shift (PTS). Although hearing loss has been studied in toothed whales and pinnipeds in situ, hearing loss has yet to be studied in baleen whales. As a result, information regarding ear anatomy and modeling is used to inform sound exposure criteria (e.g., threshold limits; Southall et al. 2019, NMFS 2024b). In turn, those criteria are used to determine how best to avoid situations when animals may develop TTS and PTS from noise-generating activities.

Strandings

In extreme cases it is possible that sound can lead to strandings, particularly in species that are deep-diving (e.g., beaked whales; see *What are strandings and Unusual Mortality Events?* and *What are some of the causes of stranding events for marine mammals?*). However, there can be challenges during the necropsy process associated with determining whether anthropogenic sound caused the strandings (see *What can we learn from strandings data?*).[8]

For More Information

- Discovery of Sound in the Sea FAQ: https://dosits.org/animals/effects-of-sound/potential-effects-of-sound-on-marine-mammals/

How does sound produced from offshore wind development compare with other industries?

- Sources of anthropogenic sound include vessels, offshore wind energy development, oil and gas exploration, military exercises, and other activities, all of which have the potential to affect marine mammals to varying degrees. Some anthropogenic sounds are high-intensity and acute (i.e., occur for short durations), while other types of sound are lower-level and chronic (i.e., occur consistently). Sound varies in intensity, frequency, and duration; all of these characteristics influence the potential for sound to affect marine mammals. For more information, see *What are the effects of anthropogenic sound on marine mammals?*
- Sounds produced in relation to offshore wind energy development vary by phase (e.g., site assessment, construction, operations, decommissioning). Some chronic sounds are lower

[7] More on hearing loss in mammals: https://dosits.org/animals/effects-of-sound/potential-effects-of-sound-on-marine-mammals/hearing-loss-in-mammals/

[8] More information on sound-related strandings: https://dosits.org/animals/effects-of-sound/potential-effects-of-sound-on-marine-mammals/strandings/

intensity ("volume") and are nearly continuous (e.g., operational turbine sound). Other offshore wind-related sounds are high-intensity and acute (e.g., pile driving of turbine foundations into the seabed).

- Offshore wind energy construction, marine oil and gas exploration, military sonar, and vessel activities all produce substantial amounts of underwater sound, but they differ in their intensity and frequency and therefore in their potential effects on marine mammals.

Detailed Answer

There is a growing concern over increased anthropogenic activity in the ocean, which has, in the last 50–70 years, resulted in substantial increases in underwater sound in the frequency ranges commonly heard by whales (Hildebrand 2005, Duarte et al. 2021); for more information, see *What are the effects of anthropogenic sound on marine mammals?*).

Sound can be high-intensity and acute (i.e., occurring for short durations), or lower level and chronic (i.e., occurring more or less continuously). Many sources of sound, such as vessels, are concentrated in coastal and continental shelf waters that are important marine mammal habitats. Offshore wind energy construction, marine oil and gas exploration, military sonar, and vessel activities all produce substantial amounts of underwater sound. Such sounds can vary in intensity/amplitude (volume), duration, and frequency ('pitch'; Figure 2).

Offshore Wind Energy Development

Sound from offshore wind energy development occurs during multiple development phases (see also *What are the major components of an offshore wind farm?* And *What are the potential effects of offshore wind development on What are the potential effects of offshore wind development on whales?*). Across all phases of development sound is emitted from vessels used for various activities (e.g., surveys, construction, maintenance). Vessels involved in offshore wind development activities are estimated to make up a very small proportion of overall vessel traffic (~2%),[9] but this does contribute to the overall soundscape. Offshore wind development involves many kinds of vessels over the life of a wind farm, and vessel needs change during each project phase. Vessel activity typically peaks during wind farm construction and immediately subsides post-construction to near pre-construction levels. A recent study found that vessels in wind farm footprints (Block Island and Coastal Virginia Offshore Wind) only increased 2.5–5 hours/month of vessel activity across development phases, and there was no substantial increase in vessel density within areas surrounding the wind farm once construction was complete (Bishop 2024; see *What factors influence vessel strike risk for large whales?*).

Site Assessment

Prior to construction of offshore wind farms, geological and high resolution geophysical (HRG) surveys are conducted. These may use a variety of broadband equipment (boomers and sparkers) and high-frequency devices, including sonar and echosounders, to characterize the surface of the seafloor. Because site assessment surveys for offshore wind are focused on characterizing the surface and subsurface of the seafloor, they do not employ the deeper-penetration sound sources, such as seismic airguns, that are used for estimating subterranean reserves of fossil fuels.[10] Offshore wind HRG surveys produce much smaller potential impact zones (e.g., areas around the sound source with elevated levels of sound) than surveys for offshore oil and gas development because, in general, they emit lower sound intensities, often at higher frequencies, and in a narrower beam width than other sound-producing activities (including

[9] Whale Fact Sheet: https://cleanpower.org/wp-content/uploads/2023/02/ACP_WhaleFactSheet_230222.pdf

[10] More information: https://www.boem.gov/renewable-energy/state-activities/offshore-wind-activities-and-marine-mammal-protection

tactical military sonar operations, as well as oil and gas exploration surveys).[11] As a result, the area within which these sounds might disturb a marine mammal's behavior is smaller than those for seismic airguns or military sonar. Currently, there are no known links between marine mammal mortalities and offshore wind site assessment surveys (Thorne & Wiley 2024; see [Does offshore wind energy development kill whales?](#)).

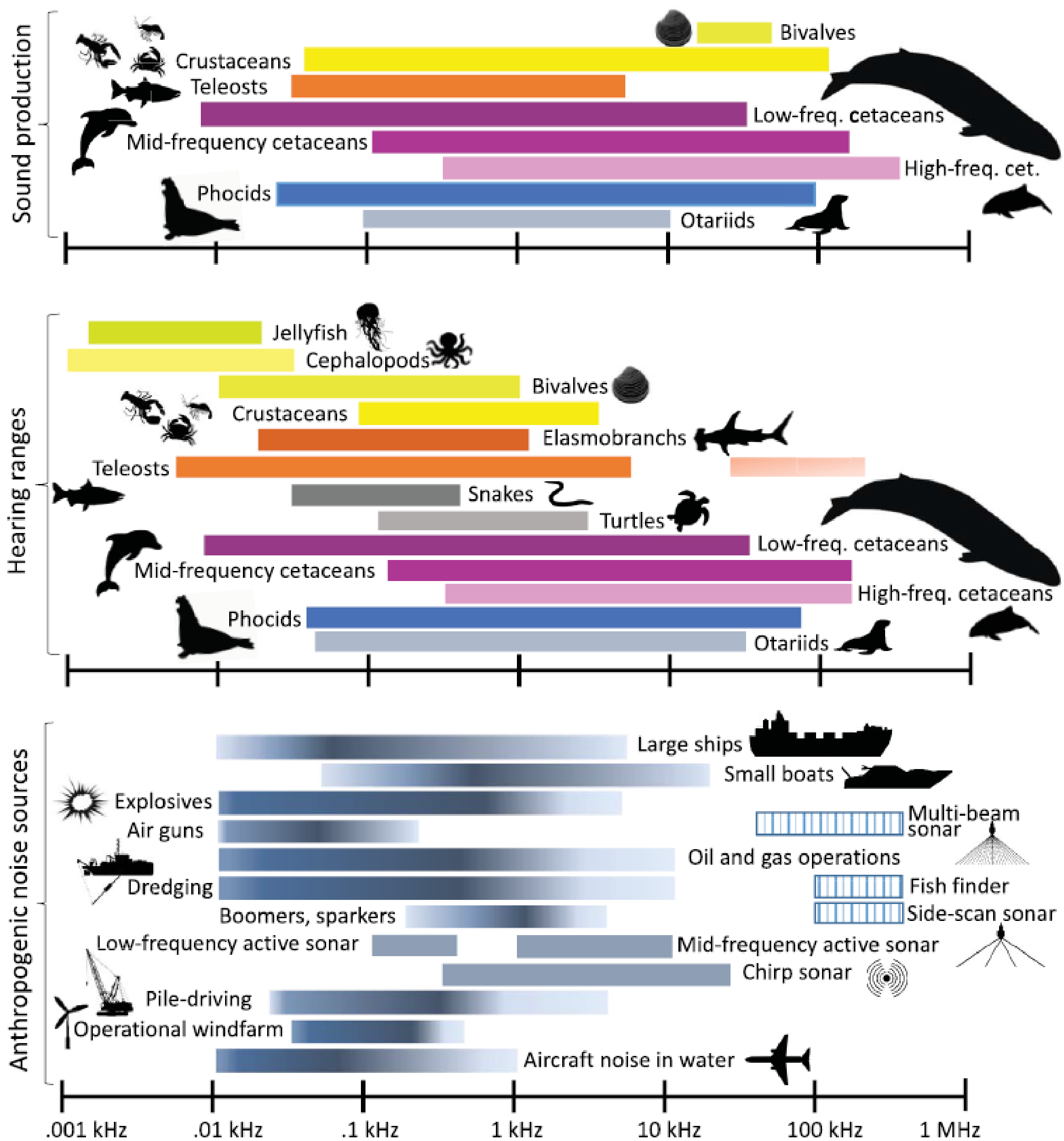

Figure 9. Hearing range of marine mammal species in comparison to anthropogenic sound source frequency. Source: Duarte et al. 2021.

[11] NOAA FAQs: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales

Construction

For traditional turbines with foundations fixed to the seafloor (e.g., monopiles, jacket foundations), construction typically includes the use of impact pile driving, in which foundations are installed into the sea floor using a hydraulic hammer. The impact of the hammer on the top of a pile during installation is the primary source of sound. Pile driving is also used in construction of the foundations of docks, bridges, and offshore oil and gas platforms, and is not unique to offshore wind development.[12] Impact pile driving produces broadband impulsive sound, and the characteristics of the sound, including intensity and distances traveled, relate to the pile configuration (e.g., size, type/material, angle), hammer impact energy, environmental properties (e.g., water depth, temperature, salinity, sediment characteristics and layering), and attenuation system used (e.g., bubble curtain; Amaral 2020). Impact pile driving sound has a distinct sound profile with an initial peak followed by a rapid decrease, finishing as a diminishing, oscillating pressure. The sound characteristics change with distance from the source.[13] There is an industry trend towards increasing foundation size (and increased energy generation capacity), leading to fewer larger turbines, which increases the sound generation for individual turbines but results in fewer sound generating events with fewer turbines to install.

Other types of pile driving technologies, such as vibratory pile driving, which are generally designed to produce less sound than traditional methods, have also been developed. Vibratory pile driving uses vibration rather than a hammer to install the pile in the sediment, and as a result the sound is classified as more non-impulsive (e.g., continuous) compared to impulsive sound produced by hammer strikes.[14] There are several other construction-related activities that also generate varying amounts of sound (such as drilling for cable burial in some locations, and removal of any unexploded ordinance that is discovered on the seafloor). In the case of pile driving foundations for offshore wind turbines, a series of mitigation measures are implemented to reduce sound impacts on North Atlantic right whales and other marine mammal species (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*).

Operations

Turbines emit sound during operations, originating from the nacelle and wind-induced vibration of the tower. These operational noise emissions are relatively low intensity and in many cases do not significantly exceed background noise levels (Amaral 2020). A recent study found that turbine sound levels were 10–20 dB below the received levels measured from ships for the same distance (Tougaard et al. 2020). However, the sound level produced depends on turbine size (sound levels increase with increased size), wind speed, and whether the technology uses a gear box or direct drive technology, the latter of which is a newer technology expected to decrease noise levels (Tougaard et al. 2020, Stöber & Thomsen 2021). Given that sounds levels are generally low compared with other phases and industries, no federal authorizations are required for sound generated during operations. However, as turbines continue to increase in size, the amount of sound emitted and potential for overlapping impact areas among turbines requires further research and potential management consideration (Betke & Bellmann 2024).

Although knowledge is limited on the effects of operational offshore wind farms on marine mammals, impacts are expected to be much lower than other more common anthropogenic sound sources, such as seismic exploration and military sonar operations (Madsen et al. 2006). A study in the Dutch North Sea found that harbor porpoise activity levels increased in a wind farm during operations compared with pre-

[12] More on sound from pile driving: https://dosits.org/galleries/audio-gallery/anthropogenic-sounds/pile-driving/

[13] DOSITS Wind Turbine Sound: https://dosits.org/animals/effects-of-sound/anthropogenic-sources/wind-turbine/

[14] What is vibratory pile driving and how does it compare to impact pile driving: https://web.uri.edu/offshore-renewable-energy/ate/what-is-vibratory-pile-driving-and-how-does-it-compare-to-impact-pile-driving/

construction, suggesting that operational sound levels were not causing avoidance (Scheidat et al. 2011). In some shallow-water environments, sound from vessel traffic can dominate the low-frequency ambient sound field. Measurements made between 14 and 40 m from turbine foundations in Denmark and Sweden showed that the sound generated from the turbine operation was only detectable above underwater ambient noise at frequencies below 500 Hz (Amaral 2020). However, under very low ambient noise conditions, it is possible that cumulative noise levels from an entire wind farm could be elevated above background noise up to a few kilometers from a wind farm (Tougaard et al. 2020)

Acoustic monitoring of the Block Island Wind Farm (BIWF) off Rhode Island found that operational sounds at 50 m from the turbine foundation were not detectable above background noise unless there was no wind and no vessels in the vicinity (HDR 2019). At the Coastal Virgina Offshore Wind (CVOW) project at frequencies below 120 Hz (audible by baleen whales), the amplitude (intensity) of sound at the turbine ranged from 120–130 decibels [dB] which was higher (10–30 dB) than those previously recorded at the Block Island Wind Farm. It is hypothesized that the higher operational noise recorded at CVOW is due to vibrations in the monopile structures, compared with jacket foundations at BIWF. At higher frequencies, results were similar across projects. Importantly, all amplitudes measured were below NOAA Fisheries thresholds for both temporary threshold shift and permanent threshold shift onset criteria (NMFS 2024b), though behavioral disruption from continuous noise may potentially occur within the measured range. For more detailed information on acoustic impacts from offshore wind, please see *What are the potential effects of offshore wind development on whales?*

Decommissioning

Decommissioning or repowering of turbines once they are no longer operational is required under project permits. There are multiple options available for decommissioning from complete removal to leaving partial structures in place (Fernandez-Betelu et al. 2024). The decommissioning process and related sound sources are largely unexplored, as only a small number of offshore wind farms have been decommissioned to date. However, it's generally believed that decommissioning sound would primarily be a by-product of the removal of substructures (Amaral 2020), which could include cutting foundation piles via explosives or water jet cutting (Nedwell & Howell 2004). As with construction, sound profiles of decommissioning activities depend on the type and size of infrastructure and specific techniques used for removal. Given that oil and gas platforms and offshore wind structures use similar foundations and subsea infrastructure, similar approaches are likely to be taken for decommissioning (Fernandez-Betelu et al. 2024). A recent study in Scotland measured sound levels during the non-explosive decommissioning of an oil and gas platform and found that daily average sound levels during the five days of decommissioning were 30–40 dB higher than prior background levels, and that sounds from direct decommissioning activities such as cutting were generally masked by vessel sounds from crane and safety and support vessels (Fernandez-Betelu et al. 2024). These levels of sound may have small-scale (a few km) and short-term behavioral effects on some marine mammals but are not high enough to cause more significant impacts (Fernandez-Betelu et al. 2024).

Oil and gas exploration

Noise from oil and gas drilling activities poses potential threats to marine mammals.[15] Drilling into the seabed begins after seismic surveys and is used to confirm the presence of hydrocarbon deposits (exploration), assess well quality (appraisal), and initiate resource extraction from multiple wells (development). Seismic surveys for oil and gas exploration employ controlled sound sources, such as airguns, to emit sound waves directed towards the ocean floor. The reflected wave patterns provide

[15] More on offshore oil and gas development and marine mammal effects: https://www.mmc.gov/priority-topics/offshore-energy-development-and-marine-mammals/offshore-oil-and-gas-development-and-marine-mammals/

insights into subsurface structures, indicative of potential hydrocarbon deposits. Airguns are designed to emit high-intensity, low-frequency sound waves capable of traveling significant distances, though recorded pulses have also been reported to contain mid- and high-frequency components, all of which have the potential to disrupt marine mammal behavior (Hermannsen et al. 2015). These activities can continue for decades over the life of an oil and gas development and impact nearby marine mammals. For example, a recent study of three offshore drilling units in eastern Canada found delphinids and beaked whales reduced their vocal activity and avoided areas during drilling operations (Martin et al. 2023). At various stages, marine mammals may also experience disturbance from sound emitted during geophysical site surveys, construction, installation of drilling platforms, structures, and pipelines, vessel activity, and decommissioning.

A recent review synthesizing 31 peer-reviewed studies from the last ~20 years highlights a range of behavioral and physiological/physical effects of seismic airguns on marine mammals, fishes, and invertebrates (Affatati & Camerlenghi 2023). Most studies focused on seismic sources used in large-scale oil and gas surveys (71%). Documented behavioral effects on mammals included changes in horizontal and vertical movements for North Sea harbor porpoises (van Beest et al. 2018) and decreased calling rates in bowhead whales in the Beaufort Sea with increasing seismic exposure (Blackwell et al. 2015). Studies also reported potential behavioral effects during/following airgun exposure in eastern Australian humpback whales (reduced migration speed, increased near-field avoidance; Dunlop et al. 2017a, Dunlop et al. 2017b, 2018), sperm whales in the Gulf of Mexico (lower pitching effort, minor foraging dive interruptions; Madsen et al. 2006, Miller et al. 2009), gray whales in Russia (abundance and distribution changes; Yazvenko et al. 2007), and some seal species in Alaska (decreased sighting rates; Harris et al. 2001).

Carroll et al. (2017) and Sole et al. (2023) reviewed the effects of seismic airgun sounds on fish and invertebrates, including critical marine mammal prey species, like zooplankton, squid, and forage fish. Two studies in these reviews found increased zooplankton mortality relative to controls following seismic airgun exposure, including mass mortality of krill larvae (McCauley et al. 2017, Fields et al. 2019). Others linked seismic survey exposure to strandings, sensory organ and tissue damage, and stress response behaviors in squid species (Fewtrell & McCauley 2012, Guerra et al. 2004). Most fish studies found no evidence of lethal injury in adults and early life stages, but some species experienced sensory organ damage, temporary threshold shifts, and elevated stress hormones, and many displayed behavioral responses (Carroll et al. 2017). Invertebrate studies reported variable impacts to adults and early life stages within and across species. For example, exposure to seismic airguns had no physical or physiological effects on adult snow crabs, but larvae had higher mortality and abnormality rates and slower development (Christian et al. 2003). In contrast, studies of southern rock lobsters demonstrated physical damage to sensory organs and impaired righting and reflexes in juveniles and adults, but larvae remained unaffected (Day et al. 2016, 2019, 2022). Studies on the effects of seismic and low-frequency sound on marine species have grown substantially over the last decade, but critical gaps remain in our understanding of potential impacts and biological sensitivities to oil and gas development activities, particularly concerning long-term and population-level effects. For marine mammals, new assessment criteria and approaches have been developed to help address these gaps and quantify empirical variability in responses to sound exposure (Southall et al. 2021).

Naval Sonar

Naval sonar uses sound waves to detect underwater objects. These active sonar systems emit pulses of sound that travel through the water and bounce off objects, which allows operators to interpret the echoes and determine the presence and location of objects. The type of sonar used by the military varies by purpose, but one common goal is the detection of submarines.

Impacts from military active sonar have been a concern for some cetacean species for the last few decades, particularly odontocetes (including dolphins, porpoises, beaked whales, and sperm whales) that use echolocation to find prey and navigate. Military sonar operations may disrupt their communication and navigational abilities, causing disorientation and making beaked whales more susceptible to stranding and subsequent death.[16] Many operational, environmental, and biological factors influence whether and how species are affected. Mid-frequency sonar operations are believed to have the most impact on marine mammals, specifically having been correlated with the highly publicized deaths of Cuvier's and Blainville's beaked whales in the Bahamas in 2000, and have coincided in time and place with additional stranding incidents as well (Evans & England 2001, Studds & Wright 2007). The 2000 Bahamas event marked the first time that the U.S. government determined mid-frequency sonar use to be the likely cause of a stranding event (Cox et al. 2005, Parsons 2017). Further investigation into this and similar beaked whale stranding events revealed that the stranded whales suffered severe diffuse congestion and hemorrhage, especially around the acoustic jaw fat, ears, brain, and kidneys, as well as gas bubble-associated lesions in their blood vessels. From these findings it has been inferred that the whales modified their diving activity in response to acoustic exposure, which induced the gas-bubble formation in body tissue and joints—much like a scuba diver suffering from "the bends"—and this was determined to be a plausible mechanism for the morbidity and mortality seen in cetaceans associated with sonar exposure (Rommel et al. 2006, Zimmer & Tyack 2007).

Vessel Traffic

Increased shipping activity and the use of commercial supertankers is considered one of the most ubiquitous sources of anthropogenic sound in the marine environment. More than 58,000 medium to large vessels are transiting the world's oceans each year, with more than 12,000 supertankers operating worldwide.[17] Sound generated from vessels primarily occurs from the vessels' propulsion systems (e.g., engines). Cavitation (the act of bubbles forming and collapsing when a propeller rotates) is a particularly significant source of sound. Concern regarding potential effects of vessels is concentrated near major active ports and heavily traveled shipping lanes (Hildebrand 2005), but the low frequency nature of vessel noise means that the sound propagates over significant distances (Duarte et al. 2021). All vessels produce sound, not just those from the shipping industry; however, this industry encompasses a large proportion of all vessels and therefore has received the most focus. However, the role of smaller vessels and ferries as sources of anthropogenic sound is being increasingly scrutinized, as these can dominate the soundscape in shallow coastal waters and at higher frequencies (Smith & Rigby 2022). Factors influencing the amount of sound generated include vessel design, size, speed, and operational conditions, and data are lacking on how much sound different vessels actually produce (Smith & Rigby 2022).

While most of the sounds produced by commercial vessels are typically below 500 Hz and are considered low frequency, data indicate that commercial vessel sound can reach frequencies well beyond 1 kHz. [18] Vessel noise may therefore interfere with vocalizations, and the masking of important biological signals by ship noise is a significant concern for marine mammals, particularly baleen whales. In some locations, a significant reduction in communication has been recorded (Hatch et al. 2012, Putland et al. 2018, Cholewiak et al. 2018). These whales produce signals within frequency ranges that overlap with the sounds produced by ships, and studies have shown that many species of cetaceans alter their vocalizations when exposed to ship traffic (Parks et al. 2007). Changes in vocalizations include increased

[16] More information on sonar: https://dosits.org/animals/effects-of-sound/anthropogenic-sources/sonar/

[17] More information on vessel numbers: https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/

[18] More information on commercial vessel traffic: https://dosits.org/animals/effects-of-sound/anthropogenic-sources/commercial-vessel-traffic/

intensity (known as the Lombard Effect), frequency shifts, alterations in calling rates, and even complete cessation of calling (Erbe et al. 2019; see *What are the effects of anthropogenic sound on marine mammals?*). Ship traffic has also been associated with elevated stress-related hormones in the feces of North Atlantic right whales (Rolland et al. 2012).

Strandings and Unusual Mortality Events

What are strandings and Unusual Mortality Events?

- Whales and other cetaceans (such as dolphins and porpoises) are considered stranded when they are found: on the shore (dead or alive), dead at sea (e.g., if the body is floating in the water), or alive at sea but unable to return to their natural habitat without human help (e.g., if trapped in shallow water or injured).
- As defined in the U.S. Marine Mammal Protection Act, an unusual mortality event (UME) is "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response."[19]
- A UME can occur over multiple years and across regions and may affect a single species or various species. Individuals or groups of animals can strand, depending on the species and situation.

Detailed Answer

Whales and other cetaceans (such as dolphins and porpoises) are considered stranded when they are found (1) dead on shore or floating in the water; (2) alive on shore and unable to return to the water; or (3) alive at sea but unable to return to their natural habitat without human assistance (e.g., if trapped in shallow water or injured).[20] Because healthy pinnipeds (e.g., seals and sea lions) come to land to rest, not all individuals found on land are considered stranded, only those found dead or in need of medical attention (which requires expert assessment to determine). In the United States., pinnipeds strand more often than cetaceans.[21] However, strandings of numerous whale species have been documented along the U.S. coastlines. These strandings are not confined to one geographic region, though different stranding patterns have emerged in relation to location and time of year. Strandings are often caused by: (1) injuries due to vessel collisions, entanglement or ingestion of active and derelict fishing gear and marine debris, or other human interactions; (2) infectious and non-infectious diseases; (3) malnutrition; (4) unusual weather events or oceanographic conditions; or (5) some combination of these or other factors. See *What are some of the causes of stranding events for marine mammals?* and *What are the drivers of recent humpback whale strandings on the U.S. Atlantic Coast?*

The National Oceanic and Atmospheric Administration (NOAA)'s Marine Mammal Health and Stranding Response Program was established under the U.S. Marine Mammal Protection Act to coordinate emergency responses to sick, injured, out of habitat, or entangled marine mammals, This coordination is achieved through collaborations with federal, state, local, and tribal governmental agencies, as well as an

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[19] NOAA definition of UME: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-unusual-mortality-events

[20] NOAA definition of strandings: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/greater-atlantic-marine-mammal-stranding-network

[21] Marine mammal health and strandings report program: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-health-and-stranding-response-program-reports

extensive network of regional stranding responders involving academic institutions, zoos and aquariums, museums, and non-governmental organizations.

'Mass stranding' or 'mass mortality event' are broad terms referring to strandings of multiple marine mammals simultaneously in the same general area.[22,23] An unusual mortality event (UME) is specifically defined in the U.S. Marine Mammal Protection Act as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." A UME can occur over multiple years and across regions and may involve a single species or multiple species (see *How and when are UMEs considered open or closed?*).

Some marine mammals strand while alive. This may happen to individuals whose health is compromised (e.g., through nutritional deficiency, Alava et al. 2019, or infection, Cools et al. 2013), who are disoriented (e.g., a dependent young animal separated from their mother), or who are experiencing other stressors. The criteria used to decide whether to release, euthanize,[24] or rehabilitate a live stranded individual include the availability of logistical support, resources, and care facilities, number and condition of the animal(s) involved, environmental conditions, and ease of handling (e.g., animal size, temperament) (Geraci & Lounsbury 2005). However, best practices regarding the decision process for responding to a live stranding require that animal welfare and the personal safety of individuals involved take precedence over all scientific data collection (Geraci & Lounsbury 2005, Boys et al. 2022). In the event of a dead stranded marine mammal, examinations and tests as part of a necropsy may be conducted to help determine the cause of death and other information about the animal's health. Data obtained from dead stranded marine mammals may vary based on the level of decomposition, as well as the availability of expertise and resources to conduct a necropsy (see *How are necropsies conducted?* and *Who funds necropsies?*).

What are some of the causes of stranding events for marine mammals?

- Strandings are often caused by (1) injuries due to vessel collisions, entanglement or ingestion of active and derelict fishing gear and marine debris, or other human interactions; (2) infectious and non-infectious diseases; (3) malnutrition; (4) unusual weather events or oceanographic conditions; or (5) some combination of these or other factors.
- Climate change has altered the migration and distribution of whale species and their prey and, in some cases, increased their interaction with vessels and other anthropogenic activities. Climate change also has the potential to contribute to changing patterns of pathogen emergence, distribution, abundance, and transmission, all of which can lead to increased strandings.

Detailed Answer

Marine mammal strandings can occur from both natural causes and anthropogenic factors. Natural causes include old age, weather, oceanographic conditions, navigation errors, or illness, though some of these may also be influenced or exacerbated by anthropogenic activities as well (e.g., stress from anthropogenic interactions could lead to weakened immune systems and therefore increased susceptibility to illness). Marine mammals that are injured or ill may move into shallow waters and become disoriented, making

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[22] NOAA information on strandings: https://www.fisheries.noaa.gov/insight/understanding-marine-wildlife-stranding-and-response#:~:text=Strandings%20of%20multiple%20animals%20(sea,Act%20sets%20out%20a%20process

[23] Marine Mammal Commission definition of mass stranding: https://www.mmc.gov/priority-topics/marine-mammal-health-and-strandings/

[24] More information on euthanasia: https://www.fisheries.noaa.gov/national/marine-life-distress/understanding-marine-mammal-euthanasia

them susceptible to stranding. In addition, natural environmental factors, such as strong offshore storms[25] and natural seismic activity (e.g., earthquakes) that disrupt or alter underwater topography, may play a role in strandings. Importantly, the susceptibility of marine mammals to human impacts varies by species and taxon; while large whales are susceptible to vessel strikes and entanglements in fishing gear and marine debris, the toothed whales, like dolphins and pilot whales, may be more susceptible to impacts from audible noise and fisheries bycatch.

Human activities may cause injury, death, illness, and stress to whales that directly contribute to strandings or mortality events. Hazards from such activities include:

- Vessel strikes (see *What factors influence vessel strike risk for large whales?*).
- Entanglement in marine debris and fishing gear, such as lines and trawl nets.
- Contaminant exposure from oil spills and other chemicals, including from agricultural and industrial runoff.
- Ingestion of plastic and other marine debris.
- Sound exposure from military sonar operations, seismic surveys (e.g., oil and gas exploration), and construction activities (see *What are the effects of anthropogenic sound on marine mammals?*).
- Habitat degradation and destruction, including increased beachfront development, that may impact feeding grounds and breeding areas for species like seals.
- Shifting prey distributions and migratory pathways due to changes in oceanographic conditions driven by climate change (see *Are whale and prey distributions changing; if so, why?*).

In recent decades, high-profile stranding and mortality events involving critically endangered North Atlantic right whales and other species, have led to increased public awareness and conservation efforts intended to reduce anthropogenic causes of mortality. Efforts in the U.S. include the expansion of stranding response networks and the formalization of a national stranding response program in 1992, public outreach and education, as well as the establishment of protected marine habitat areas. Additional efforts include the implementation of government regulations and guidelines, such as vessel speed limits starting in 2008 and fishing gear modifications starting in the 1990s (e.g., dolphin-safe tuna), increased monitoring, noise attenuation requirements and sound limits for certain activities, and development of species management plans. Public awareness of the factors contributing to stranding events can help support conservation and management efforts.

For More Information

- Understanding Marine Wildlife Stranding and Response: https://www.fisheries.noaa.gov/insight/understanding-marine-wildlife-stranding-and-response#why-do-animals-strand

What are the drivers of recent humpback whale strandings on the U.S. Atlantic coast?

- There has been a high level of public interest in recent strandings and mortalities of large whales along the U.S. Atlantic coast. In 2017, NOAA declared an 'unusual mortality event,' or UME, for humpback whales. See *What are strandings and UMEs*?

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[25] NOAA Fisheries post-hurricane dolphin displacement: https://www.fisheries.noaa.gov/marine-life-distress/displaced-dolphins-post-hurricane-response

- A recent scientific journal article (Thorne & Wiley 2024) used strandings data to examine patterns of strandings, mortalities, and serious injuries for humpback whales on the U.S. Atlantic coast from 1995–2022 to better understand potential factors contributing to these events.
- Findings suggest that vessel strikes are a key driver, with a threefold increase in vessel strike-related mortalities from 1995–2015 to 2016–2022. In particular, increases in vessel strikes occurred in waters off New York and Virginia, likely due to combined effects of changes in habitat use by whales, surface feeding behavior, occurrence in shallow waters, prevalence of juvenile whales, and increases in vessel traffic in these regions.
- Thorne & Wiley (2024) found no evidence that offshore wind development contributed to recent strandings or mortalities and serious injuries of humpback whales. This conclusion was based on a comparison of the patterns of mortalities and serious injuries with the timing and location of offshore wind energy site assessment surveys and construction activities. See *Does offshore wind energy development kill whales?*

Detailed Answer

There has been a high level of public interest in recent strandings and mortalities of large whales along the U.S. Atlantic coast. Strandings have occurred in the region throughout history, due to both natural and anthropogenic factors (Brown & Wiedenmann 2024), though stranding rates have fluctuated over time (see *Why are baleen whales dying right now in the Northwest Atlantic?*). There has been substantial media coverage of claims about a connection between large whale strandings and offshore wind development; however, current scientific knowledge does not suggest any link between large whale strandings and offshore wind activities (see *Does offshore wind energy development kill whales?*).

The population of humpback whales in the western North Atlantic has recovered to the point that they are no longer considered "Endangered" or "Threatened" under the Endangered Species Act. Thus, there are more whales present today in this ecosystem than there were several decades ago. This population has experienced increased levels of strandings and mortalities in recent years, leading NOAA to declare an 'unusual mortality event' (UME) in 2017, which included humpback whale deaths from 2016 (see *What are strandings and UMEs?*). In a recently published scientific journal article, Thorne & Wiley (2024), examined the spatiotemporal patterns of humpback whale strandings, mortalities, and serious injuries along the U.S. Atlantic coast from publicly available data from 1995–2022 to investigate the ecological and anthropogenic drivers of those strandings.

Key findings from this study include:

- **Increasing vessel traffic.** New York and Virginia were notable hotspots for vessel strikes, showing the greatest increase in humpback whale mortalities and serious injuries. These hotspots coincide with locations of substantially increased (approximately doubled) container ship traffic since 2016, and particularly since 2020. This represents part of a larger global trend of increased vessel traffic with a four-fold increase in commercial vessel movements between 1992 and 2012 (Robbins et al. 2022).
- **Increasing vessel strikes.** Based on the subset of humpback whale mortalities and serious injuries with known causes of death, entanglements were observed significantly more than vessel strikes prior to 2016. However, from 2016–2022, there has been a three-fold increase in observed vessel strikes, and similar numbers of entanglements and vessel strikes were observed during this period. See *What factors influence vessel strike risk for large whales?*
- **Changes in spatial and temporal patterns.** Of the Atlantic coast states, Delaware, New Jersey, and New York have experienced the highest percent increase in humpback whale strandings when comparing 1995–2015 to 2016–2022. Strandings especially increased in winter months.

- **Shifts in whale distributions and other ecological factors.** In addition to increases in vessel traffic, changes in humpback whale habitat use due to climate change and shifting resource availability contribute to increased strandings (see *How is climate change affecting large whales?*). Historical records suggest that humpbacks were relatively rare in nearshore waters of the New York Bight until the 1980s (Brown & Wiedenmann 2024). The abundance of humpback whales in the Gulf of Maine has increased, as has the use of the New York Bight and Mid-Atlantic region as key foraging grounds, in part due to increases in the stock of Atlantic menhaden, a fish in the shad family), while other prey species like Atlantic herring[26] and Atlantic mackerel have decreased (NOAA 2023, Brown & Wiedenmann 2024). Even small shifts in prey distributions can lead to increases in vessel strikes if whales become more prevalent in shipping lanes (Berman-Kowaleski et al. 2010). Humpback whales foraging on menhaden often use surface foraging behavior in shallow nearshore waters, increasing susceptibility to vessel strike (Stepanuk et al. 2021, Brown & Wiedenmann 2024). Furthermore, a majority of humpback whales foraging in these regions are juveniles (Stepanuk et al. 2021), who may be more susceptible to risk due to inexperience around vessels. See *Are whale and prey distributions changing; if so, why?*
- **No evidence of offshore wind as a contributing factor.** While offshore wind development has the potential to affect whales (see *What are the potential effects of offshore wind development on whales?*), the study found no evidence that offshore wind development contributed to recent strandings or mortalities and serious injuries of humpback whales. During the study period (1995–2022), only two wind farms were built in the region, so most offshore wind-related activities consisted of site assessment surveys prior to construction of planned projects. The timelines and spatial extent of offshore wind site assessment surveys and construction activities did not correspond with patterns of humpback whale strandings. For example, only a single offshore wind site assessment survey was authorized in Massachusetts in 2016, but elevated strandings were observed from North Carolina to Rhode Island, while Massachusetts showed a lower number of strandings in 2016 compared to previous years. See *Does offshore wind energy development kill whales?*

These findings provide strong evidence for the key role that vessel strikes[27] have played in the recent humpback whale UME due to changes in habitat use, surface feeding behavior, occurrence in shallow waters, prevalence of juvenile whales, and increases in vessel traffic in these regions. Thorne and Wiley (2024) did not find evidence for any role of offshore wind development in causing mortalities and serious injuries of the humpback whales. This study suggests additional research is needed to improve understanding of how factors like vessel size, adherence of vessel operators to existing speed restrictions, and effectiveness of current management designed for North Atlantic right whales (e.g., Seasonal Management Areas) may influence the risk of vessel strike for humpback whales.

Why are baleen whales dying in the Northwest Atlantic and is this a new phenomenon?

- Generally, existing evidence suggests that the main anthropogenic causes of death for baleen whales are vessel strikes and entanglement in fishing gear. However, the cause varies by species. While we lack information for many whale mortalities (e.g., those that aren't detected or necropsied, or for which cause of death cannot be determined; see *What are the biases and limitations of stranding data?*), data suggest that the greatest risk to humpback whales is from

[26] Atlantic herring stock assessments: https://www.nefmc.org/library/atlantic-herring-stock-assessments
[27] NOAA Information on Humpback Whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/frequent-questions-2016-2025-humpback-whale-atlantic-coast-unusual

vessel collisions (50% of necropsies showed evidence of vessel interaction; see *How are necropsies conducted?*), whereas 65% of North Atlantic right whales that have been killed or injured were entangled in fishing gear.

- Recent increases in the number of baleen whale deaths in the Northwest Atlantic region relate to a combination of natural and anthropogenic factors. These may include shifting prey and whale distributions inshore, infectious disease, and changes in the locations and amount of shipping activity, leading to increased interactions with vessels. See *Are whale and prey distributions changing; if so, why?*

Detailed Answer

As of April 2024, there were four active **unusual mortality events**, or UMEs, for marine mammals in the U.S. (Table 1; see *What are strandings and UMEs?*).[28] A panel of experts with knowledge and experience in marine science, marine mammal science, veterinary and husbandry practices, marine conservation, and medical science—known as the Working Group on Marine Mammal Unusual Mortality Events—determines when a UME is occurring. UME designation may provide additional financial support for stranding response and investigations into the causes of the event. Of the active UMEs in April 2024, all four are in the Atlantic and three involve whales: humpback whales, minke whales, and North Atlantic right whales. A fifth UME involving grey whales in the Pacific was recently closed.[29] See *How and when are UMEs considered open or closed?*

Elevated humpback whale mortalities have been observed along the U.S. Atlantic coast (from Maine to Florida) since January 2016.[30] The highest numbers of strandings have occurred off New York and Massachusetts, followed by Virginia, New Jersey, and North Carolina, but strandings have been recorded during this period off all Atlantic coast states (view the locations). Necropsies were conducted on only about half of the carcasses due to various reasons, including advanced decomposition and carcass accessibility. Of the individuals examined, approximately 40% exhibited evidence of human interaction, either vessel strike or entanglement (see *How are necropsies conducted?*). Some of the remaining whales had other causes of death. Importantly, the distribution of humpback whales along the U.S. Atlantic coast has varied in recent years, including some novel habitat use (Aschettino et al. 2020, Brown et al. 2022). Whale population growth could also influence long-term stranding rates as the population recovers from historical whaling (Stevick et al. 2003), but the drastic increase of stranded humpback whales detected in 2016 onwards was not matched with a similar drastic population increase. Rather, changes in whale habitat use and behavior may be important factors in stranding rates. For example, young humpback whales have been observed foraging close to shore on prey that are aggregated in shallow coastal areas (e.g., Atlantic menhaden in the New York/New Jersey region; Lucca & Warren 2019), where human activity, such as passenger and shipping vessel traffic, is prevalent (Stepanuk et al. 2021, King et al. 2021). The presence of these animals close to shore could increase both the detection of injured, stranded, or dead animals, and the risk of lethal interaction with known anthropogenic threats, such as fixed fishing gear and vessel traffic (Stepanuk et al. 2021). In addition, changes in the density, volume, and speed of vessel traffic and fishing effort could also impact interaction rates with human activities. While 2023 saw an increase in the number of strandings of humpback whales compared to 2021 and 2022, the number

[28] NOAA Fisheries information on Unusual Mortality Events: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-unusual-mortality-events

[29] Active and closed Unusual Mortality Events: https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events

[30] Humpback whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2024-humpback-whale-unusual-mortality-event-along-atlantic-coast

and location were similar to observations in 2017 and 2020.[31] See *What are the drivers of recent humpback whale strandings on the U.S. Atlantic Coast?*)

North Atlantic right whales, which currently number around 360 individuals, have experienced elevated levels of mortality and injury in eastern North America since 2012 (from Newfoundland to Florida; view an interactive map). A UME was declared for this species in the U.S. in 2017 and is still ongoing.[32] Mortalities and injuries were first detected in Canadian waters related to the movement of many North Atlantic right whales into the Gulf of Saint Lawrence starting in 2015 (see *Are whale and prey distributions changing; if so, why?*). In 2017, seventeen right whales were observed killed or injured in the Gulf of Saint Lawrence, a region featuring some of the largest densities of pot and trap fishing in Canada (Davies et al. 2019). The whales were killed by entanglement in snow crab and other fishing gear and blunt trauma from vessel strikes, as well as undetermined causes. Following these events, monitoring and risk reduction regulations were rapidly implemented by the Canadian government, including closing the snow crab fishery. Since 2017, Canada has maintained a robust mitigation and monitoring program for North Atlantic right whales.[33] Increased mortalities in U.S. waters started in 2017, prompting the declaration of a UME. The UME has since been expanded to include individuals that are dead, seriously injured, or have a sublethal injury or sickness. The leading causes of the UME are entanglement in fishing gear (65%) and vessel strikes (15%).[34] Remaining cases were birth-related or were dependent calves harmed by injuries to their parent (3%), were not examined (8%), or had undetermined cause of death (9%). The highest number of annual mortalities and injuries occurred in 2017 and 2018, with lower but still elevated numbers since.

Similar to humpback and North Atlantic right whales, minke whales from Maine to Georgia have experienced elevated mortalities since 2017 (interactive map). Preliminary findings from necropsies on minke whales have found evidence of human interaction and infectious disease.[35] The widespread nature of these three UMEs along the Atlantic coast of North America and the temporal scale (2017–present) suggest a range of causes, primarily vessel strikes and entanglement, as well as disease and other factors.

Table 1. Active unusual mortality events (UMEs) for marine mammals in the United States, including year declared, name of the UME, species affected, location, and the causes (as of 9 May 2025). Source: NOAA website on UMEs.

Year	UME	Species	Location	Cause(s)
2018	Atlantic Minke Whale	Minke Whale	Atlantic Ocean	Suspected human interaction (entanglement)/Infectious disease
2017	North Atlantic Right Whale	North Atlantic right whale	Atlantic Ocean, Canada, and U.S.	Human interaction (vessel strike/entanglement)
2017	Atlantic Humpback Whale	Humpback whale	Atlantic Ocean	Suspected human interaction (vessel strike)

[31] More information on humpback whale strandings: https://e360.yale.edu/features/humpback-whale-strandings-u.s.-east-coast
[32] North Atlantic right whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2024-north-atlantic-right-whale-unusual-mortality-event
[33] Canadian efforts to reduce north Atlantic right whale mortality: https://www.canada.ca/en/fisheries-oceans/news/2024/03/government-of-canada-announces-the-2024-measures-to-protect-north-atlantic-right-whales.html
[34] North Atlantic Right Whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2024-north-atlantic-right-whale-unusual-mortality-event
[35] Minke Whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2025-minke-whale-unusual-mortality-event-along-atlantic-coast

For More Information

- More information on unusual mortality events: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-unusual-mortality-events
- The humpback whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2025-humpback-whale-unusual-mortality-event-along-atlantic-coast
- The North Atlantic right whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2025-north-atlantic-right-whale-unusual-mortality-event
- The minke whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2025-minke-whale-unusual-mortality-event-along-atlantic-coast
- The Working Group on Marine Mammal Unusual Mortality Events: https://www.fisheries.noaa.gov/national/marine-life-distress/noaa-fisheries-partners-spotlight-working-group-marine-mammal-unusual-mortality-events
- Marine Mammal Commission 2023 update on strandings of large whales along the U.S. Atlantic Coast: https://www.mmc.gov/wp-content/uploads/Update-on-Strandings-of-Large-Whales-along-the-East-Coast-2.21.2023.pdf

What can we learn from stranding data?

- Strandings can provide important information on disease, health, and causes of death.
- Stranding data are especially important for learning about susceptible and rare populations/species.
- Stranding and entanglement response networks fill a valuable bio-surveillance role, as they are often the first to detect threats to marine mammal populations.

Detailed Answer

Marine mammals are considered stranded when found dead, either on land or floating in the water, or alive on land but are unable to return to the water or are in need of medical attention (see *What are strandings and Unusual Mortality Events?*). The data obtained from stranding events are vital to understanding marine mammal biology, physiology, and health, which allows us to better evaluate the risk factors for both individuals and populations of marine mammals. Stranding events can provide a key set of information that would not otherwise be attainable, as marine mammals spend all or most of their lives in marine environments and are difficult to study. In addition, stranding response network partners fill a valuable role related to bio-surveillance, as they are often the first to detect particular threats to marine mammal populations.[36]

Stranding data have been incorporated into scientific analyses for decades and can provide an understanding of marine mammal health and how it varies across space and time (Wiley et al. 1995, Betty et al. 2020). These data can inform our understanding of species presence and distributions, population health, contaminant levels, and human interactions with marine mammals. Examples of these include:

- **Species presence and distributions:** Some rare marine mammal species have never been observed alive and have only been discovered based on the presence of stranded, dead individuals. An example of this is the Perrin's beaked whale in the Pacific, which was only recently recognized as a unique species based on the discovery of just five individuals that stranded over a 20-year period (Dalebout et al. 2002). Changes in the spatiotemporal patterns of strandings can

[36] Marine mammal health and strandings response program: https://www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-health-and-stranding-response-program

also serve as indicators of underlying changes due to anthropogenic activities or naturally occurring events in the populations of common species (Byrd et al. 2014).

- **Population health:** In some instances, it is possible to extrapolate from stranding occurrences to understand broader population health, though there are important caveats (See *What are the biases and limitations of stranding data?*). A study of killer whales in the northeastern Pacific Ocean and Hawaii found that necropsy and pathology results indicated a range of causes of mortality, including infectious disease, trauma, malnutrition, and bacterial infections, and that there was a relationship between cause of death and body condition (i.e. a measure of animal health based on blubber, size, and fatness; Raverty et al. 2020). As another example, necropsy results from gray whales in the Pacific have been used to understand rates of malnutrition, with 26% of stranded gray whales being severely emaciated, likely related to various factors including environmental change and prey shifts (Raverty et al. 2024). See *How are necropsies conducted?*
- **Contaminant levels:** Contaminants in the ocean typically biodegrade (or break down) quite slowly, and therefore can accumulate in animals' bodies, particularly species that are towards the top of the food chain. This is particularly important for toothed whales, due to the higher trophic level of their prey; a study of tissue samples collected from 83 toothed whales found that there were differences in the toxins and contaminants between species, sex, and age classes, and suggested that the toxin levels observed in tissues from stranded animals could lead to health declines, especially when combined with other impacts (Page-Karjian et al. 2020).
- **Human Interactions:** One of the goals of conducting stranding assessments and necropsies is to determine whether human interactions were the cause of death (see *What are the biases or limitations of stranding data?*). Stranding data can also provide insight into novel human interactions with marine mammals, such as recent detections of plastic and debris in the digestive tracts of stranded animals (Alzugaray et al. 2020).

Ultimately, stranding data are incredibly useful to better understand the health, biology, and risks for marine mammal species. These data can support other forms of monitoring and assessment, such as shipboard or plane-based surveys, and field-based health assessments (e.g., biopsy collection, photogrammetry). However, it is important to understand that some scientific questions are difficult to address or answer due to biases and limitations of stranding data (see *What are the biases or limitations of stranding data*?).

What are the biases or limitations of stranding data?

- Detecting strandings and determining their causes is challenging.
- Many factors influence stranding occurrences and rates. This means it is difficult to understand whether observed changes in the timing, location, or rate of strandings reflect actual changes in mortality in a population.
- Availability of stranding data depends on strandings being detected by people (e.g., some animals never wash ashore), knowledge of how to report the stranding, and stranding network partners that are able to further investigate an event when it is detected and reported.

Detailed Answer

It can be hard to draw definitive conclusions from stranding data when asking certain scientific questions, such as whether the timing, location, or annual rate of strandings has changed over time for a given population. This is because many factors affect how strandings are detected and reported (Figure 3). If these sources of variability are not considered, results can be misleading and lead to incorrect conclusions about trends or causes—what statisticians call "biased." In this context, bias means the analysis does not reflect reality, often because of too few or non-random observations or missing important information. Factors that affect numbers of reported strandings include:

- **Actual number of strandings** – Multiple factors influence the true number of strandings that occur over time, including (1) population abundance (e.g., an increase in the size of the population may lead to an increase in the number of stranded animals); (2) changes to mortality and serious injury rates due to natural or human-related factors (e.g., changes in the type, number, severity, and/or duration of human interactions); and (3) habitat and behaviors that may influence likelihood of beaching and/or increased susceptibility to human impacts.
- **Number of stranded marine mammals detected –** While ideally all stranded marine mammals are detected, known or detected strandings only represent a fraction of the true or actual number of strandings. This unobserved number of strandings has been termed "cryptic mortality." Multiple factors influence the likelihood of detection, including (1) animals' abundance and distribution, as detection likelihood is higher for marine mammals who typically use habitat closer to coastlines and are more likely to strand on shore (rather than sink or get carried out to sea) or those with larger populations; (2) environmental conditions and habitat, including ocean currents that may affect the carcass speed and trajectory, ocean temperature and salinity (affects buoyancy and decomposition rates of dead marine mammals), and scavenging of carcasses by predators; and (3) human population density, as there are higher detection rates in areas with higher concentrations of people.
- **Number of stranded marine mammals reported** – Accurate stranding rates rely on the consistent reporting of stranded marine mammals and consistency of network partners, who maintain records. Factors that influence reporting include the presence of local active stranding networks and public awareness, so people know how and why to report strandings. Reporting gaps and inconsistencies can also occur when stranding network partner organizations close or restructure their priorities.

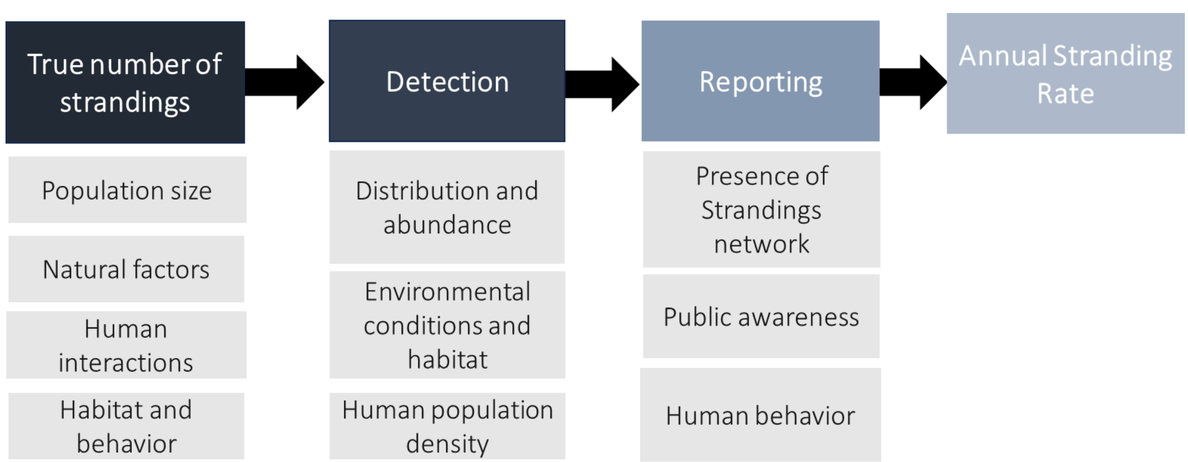

Figure 3. Potential factors influencing annual marine mammal stranding rates. Factors can influence the true number of strandings, the likelihood of detecting strandings when they occur, and/or the likelihood of detected strandings being reported to the proper authorities.

Detecting strandings and detailing stranding causes is complicated. Simple examination of the number of strandings may be misleading (Faerber & Baird 2010). Marine mammal annual stranding rates (e.g., the number of strandings reported per year) can be influenced by the true number of seriously injured or dead animals, the ability to detect stranded animals (the number of known or observed strandings represents only a fraction of the true number, with unobserved mortality termed "cryptic mortality"; Pace

III et al. 2021), and the likelihood that detected strandings are reported. The true number of strandings is influenced by marine mammal population size: if a constant proportion of the population is stranding over time, yet the population is growing, then a larger number of individuals will strand as the population increases (Woodhouse 1991, Pyenson 2011). In addition, changes to mortality and serious injury rates may occur due to changes in natural or human interactions (including type, severity, location, and duration). Finally, species or individual behavior may impact stranding rates. Hypotheses for behavioral impacts on strandings include possible disruption of strong social networks (Oremus et al. 2013), or age- or sex-based behavioral differences that influence stranding risk, such as juvenile humpback whales occurring disproportionately closer to shore (Stepanuk et al. 2021), or female humpback whales occurring closer to shore than males in Hawaiian waters (Craig et al. 2014), thus leading to a higher probability of juvenile and female strandings, respectively.

Detection factors that influence observed marine mammal stranding rates include habitat, distribution, abundance, oceanographic conditions, and human population density and amount of monitoring or reporting effort. A species' distribution and its proximity to coastlines could influence observed stranding rates, as strandings that occur farther offshore are less likely to be detected (Norman et al. 2004, Faerber & Baird 2010, Stepanuk et al. 2021). If the typical habitat of individuals is close to shore, the probability of stranding along a shoreline, and therefore being detected, is higher (Geraci & St Aubin 1979, Faerber & Baird 2010). In addition, if the distribution of a population shifts closer to shore, the probability of detecting strandings will increase, even when the population is experiencing constant rates of mortality (Norman et al. 2004, Faerber & Baird 2010, Stepanuk et al. 2021). Oceanographic drivers, including ocean currents, sea surface salinity, and sea surface temperature, may also influence stranding rates. The drift and movement of floating carcasses and weakened live animals at sea is primarily driven by ocean currents, either increasing stranding rates by transporting more individuals towards land (e.g., Cape Cod – Pugliares et al. 2016) or decreasing rates by pulling carcasses and weakened animals away from shore (e.g., Hawaii - Faerber & Baird 2010). In addition, lower sea surface salinity could reduce buoyancy, and sea surface temperature influences both decomposition rate and buoyancy (Faerber & Baird 2010). The probability of detection is also consistently higher in areas with higher concentrations of people, due to the distribution of homes, accessible coastlines, recreational vessels, and vacation hotspots (Norman et al. 2004, Faerber & Baird 2010). Similarly, there may be seasonal variation in detections, with higher rates during warmer summer months when more people spend time at coastlines (Norman et al. 2004). Warmer summer months may also correspond with oceanographic drivers and seasonal species distribution shifts to compound the probability of detecting strandings (Norman et al. 2004). To properly understand and analyze stranding data, particularly when assessing changes in stranding rates in space or time, it is important to account for these influences.

Variation in reporting of strandings can lead to biases that make it difficult to effectively incorporate stranding data into data-driven analyses. First, the presence of an official and active stranding network influences the rate of reporting, as does general public awareness of why and how to report stranded marine mammals (Norman et al. 2004). There may also be variability in human behavior when reporting, as some individuals may be more likely to report than others.

The research questions that can be addressed with this type of data and the ways in which biases need to be accounted for must be carefully considered during analysis and reporting. Despite these limitations, ultimately, stranding data are incredibly useful to better understand the health, biology, and risks faced by marine mammals, especially for rare species, and can support other forms of standardized monitoring and assessment, such as surveys and in-field biological sampling.

How and when are Unusual Mortality Events (UMEs) considered open or closed?

- The U.S. Working Group on Marine Mammal Unusual Mortality Events is a panel of scientific experts charged with investigating potential UMEs and providing a recommendation to NOAA Fisheries and/or the U.S. Fish and Wildlife Service as to whether the agency should formally declare or close a UME.
- When assessing whether a UME is taking place, the Working Group will review historical and current stranding data, along with other relevant information, and determine whether the situation meets any of seven established UME criteria.
- The UME investigation remains open until the Working Group determines that the criteria under which the UME was declared have either been resolved, or become persistent (e.g., a new baseline under which strandings would no longer be considered unusual). In these circumstances, the Working Group will then recommend closure of the UME to NOAA Fisheries.

Detailed Answer

As defined in the U.S. Marine Mammal Protection Act (MMPA), an unusual mortality event (UME) is "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." A UME can occur over multiple years and across regions and may affect a single species or multiple species. Individuals or groups of animals can strand dead or alive, depending on the situation. See *What are strandings and Unusual Mortality Events?*

Founded in 1991 and formalized by Congress through amendments to the MMPA in 1992, the Working Group on Marine Mammal Unusual Mortality Events (hereafter 'the Working Group'), [37] coordinated by the NOAA Fisheries Marine Mammal Health and Stranding Response Program (hereafter 'the Program'), is charged with investigating potential UMEs and providing a recommendation to NOAA Fisheries, and/or the U.S. Fish and Wildlife Service,[38] about when to formally declare a UME. The Working Group currently includes 12 voting members who have specialized expertise in marine science, marine mammal science, marine mammal veterinary and animal care practices, marine conservation, and/or medical science. Working Group members are chosen to balance collective expertise across the various disciplines required by the MMPA.

When assessing whether a UME is taking place, the Program compiles a consultation package for the Working Group, which includes both historical and current stranding data (see other FAQs in *Strandings and Unusual Mortality Events* section of this document), along with other relevant information. The Working Group then has 48 hours to evaluate this information and decide if the situation meets any of the seven established UME criteria,[39] which include:

1. A marked increase in the magnitude or a marked change in the nature of morbidity (illness), mortality (death), or strandings when compared with prior records.
2. A temporal change (change in timing) in morbidity, mortality, or strandings is occurring.
3. A spatial change in morbidity, mortality, or strandings is occurring.
4. The species, age, or sex composition of the affected animals is different than that of animals that are normally affected.

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[37] Working Group on Marine Mammal Unusual Mortality Events: https://www.fisheries.noaa.gov/national/marine-life-distress/noaa-fisheries-partners-spotlight-working-group-marine-mammal-unusual-mortality-events

[38] NOAA Fisheries has jurisdiction over all cetaceans and all pinnipeds except the walrus, while the U.S. Fish and Wildlife Service has jurisdiction for walruses, sea otters, manatees, and polar bears. For the remainder of this FAQ, we will focus on the UME process for cetaceans.

[39] More information on UME criteria: https://www.fisheries.noaa.gov/insight/understanding-marine-mammal-unusual-mortality-events#what-criteria-define-an-ume?

5. Affected animals exhibit similar or unusual pathologic findings, behavior patterns, clinical signs, or general physical condition (e.g., blubber thickness).
6. Potentially significant morbidity, mortality, or stranding is observed in species, stocks, or populations that are particularly vulnerable (e.g., listed as depleted under the MMPA, threatened/endangered under the ESA). For example, stranding of three or four endangered right whales may be cause for great concern, whereas stranding of a similar number of fin whales may not.
7. Morbidity is observed concurrent with or as part of an unexplained continual decline of a marine mammal population, stock, or species.

Following their assessment, the Working Group's recommendation to declare a UME is sent to NOAA's Assistant Administrator for Fisheries for further review, and if the recommendation is endorsed by NOAA Fisheries or U.S. Fish and Wildlife Service (depending on the marine mammal species involved), then a UME is officially declared for the affected marine mammal species.

For each UME, an Investigation Team (typically including government and academic biologists, veterinarians, and members of the relevant marine mammal stranding network) work to determine its cause. A UME investigation remains open until the Teams determines that the criteria under which the UME was declared have resolved or have become persistent, in which case they recommend a closure of the UME to the Working Group. "Persistent" data during a UME may indicate a new baseline under which strandings would no longer be considered unusual. If the Working Group agrees with a closure recommendation, it is then passed to NOAA Fisheries to review and make a final decision.

An example of the UME process (from declaration to close) is the 2019–2023 Eastern North Pacific Gray Whale UME.[40] An increased number of gray whale strandings (criterion #1) triggered a consultation with the Working Group, which led to declaration of the UME in 2019. The highest rate of strandings occurred between mid-December 2018 through December 2020, resulting in 690 gray whale strandings along the coast of the United States, Canada, and Mexico. Necropsy results from a subset of the dead whales indicated malnutrition as a common cause of death, with no signs of underlying infections (see *How are necropsies conducted?*). Observations also showed that the nutritional condition of live gray whales in Mexico was worse leading into and during the UME than in previous years. The Working Group attributed these nutritional challenges to localized changes in the ecosystem of the northern Bering and Chukchi Seas, affecting both the availability and quality of prey, causing a nutritional deficit that led to increased mortality rates during the whales' northward migration, as well as decreased birth rates. These impacts led to a decline in the overall population abundance. The population recovered a few years after the declaration of the UME, when stranding rates declined to pre-UME numbers. The event was officially closed on November 9, 2023, and the closure was announced in March 2024 (it is possible for a UME closure to be backdated based on the relevant data).

How are necropsies conducted?

- Similar to an autopsy in humans, a necropsy is the examination of a deceased animal to identify cause of death and collect other information on the health of the individual, the species, and the marine environment.
- In the United States, whale necropsies are conducted by organizations that are members of the National Marine Mammal Stranding Response Network. All reported strandings are documented,

[40] Pacific Gray Whale UME: https://www.fisheries.noaa.gov/national/marine-life-distress/2019-2023-eastern-north-pacific-gray-whale-ume-closed

but it is not possible to conduct necropsies in many cases due to human safety, the state of carcass decomposition, stranding location, or other reasons.

- Necropsies can provide valuable information, but cause of death cannot always be determined. Complicating factors include the level of decomposition, inability to collect or process samples due to limited accessibility or resources, inconclusive test results, and difficulty identifying multiple factors that may contribute to the cause of death.

Detailed Answer

Similar to an autopsy in humans, a necropsy is the examination of a deceased animal to identify cause of death. It may include the collection of biological samples from a deceased animal and/or the synthesis of known history of the animal, particularly during the time leading up to the stranding. For cetaceans and other marine mammals, necropsies provide an important, rare insight into the physiology and health of these species that spend their lives at sea and are therefore difficult to study. In the United States, necropsies are conducted by members of the National Marine Mammal Stranding Response Network. The Network is overseen by the Marine Mammal Health and Stranding Response Program (MMHSRP) at NOAA Fisheries' Office of Protected Resources; the MMHSRP was formalized as part of amendments to the U.S. Marine Mammal Protection Act in 1992.[41] Network members include nonprofit organizations (e.g., zoos and aquaria), museums, universities, and state, federal, local, and tribal governments who have experienced personnel and are trained in marine mammal stranding response.

Stranding network members are required to document all reported strandings as is feasible for both live and dead stranded animals, and at a minimum must report basic animal information (e.g. date, location, species, etc.) and external observations of the animal, including morphology, life history, and general health (this is called "Level A data").[42,43] The opportunity to conduct a full necropsy and investigation of a dead stranded animal, however, is dependent on a number of factors, including condition of the carcass, stranding location, weather, and financial, scientific, and logistical resources (see *Who funds necropsies?*). For partially decomposed carcasses, it may not be possible to obtain comprehensive information. If animals are stranded in unsafe locations (e.g., rocky coastlines, slippery intertidal regions) or die at sea, additional resources may be needed to relocate the animal (if possible) to a location where personnel can safely operate around the animal, such as a beach or dock. In addition, necropsy completion may be complicated by inclement weather and environmental factors. For example, because some necropsies may require over 10 hours to complete, winter months may limit the ability to conduct a thorough investigation. Many resources are required to effectively conduct necropsies, including highly trained and experienced personnel, including a designated safety officer, and in many cases, industrial machinery, such as backhoes and excavators. Trained necropsy coordinators and staff may need to travel long distances on short notice to conduct high-priority necropsies. The resources required to conduct a full necropsy of large whales are also much greater than for small marine mammals, as the amount of machinery and number of trained personnel required to conduct a necropsy typically scale with animal size.

Preliminary Necropsy Data Collection

Before any necropsy begins, it is important to document baseline information about the animal, including the time, date, and location of stranding, environmental conditions, any behavior documented prior to

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[41] Marine mammal health and stranding response program: https://www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-health-and-stranding-response-program

[42] More information on Level A data collection: https://www.fisheries.noaa.gov/national/marine-life-distress/level-data-collection-marine-mammal-stranding-events

[43] Level A data form: hdtps://media.fisheries.noaa.gov/2021-07/Level%20A%20form_2024%20Fillable.pdf?

stranding and/or previous documented stranding history (which can help inform understanding of body condition and possible causes of death), and if the animal was euthanized. The history of some stranded animals can be determined from documentation of individuals (e.g., humpback whales have natural markings on the underside of their tail, or fluke, that can be used for individual identification; North Atlantic right whales have unique patterns of callosities on their skulls that can allow for individual identification), or from repeated reports of an individual in distress or in novel habitat (e.g., rare toothed whales occurring in harbors and rivers, entangled whales).

Importantly, it is necessary to document any initial signs of human interaction, such as rope, gear, or debris on the animal, or sharp lacerations indicative of interaction with a vessel propeller. This process is called human interaction evaluation. The detailed process to assess and evaluate stranded7 animals for human interaction is documented in the "Handbook for Recognizing, Evaluating, and Documenting Human Interaction in Stranded Cetaceans and Pinnipeds" (Barco & Touhey 2006). This document outlines the standardized reporting and data collection process required to eventually determine whether death occurred due to human causes, which is vital to determining population sustainability and acceptable levels of "take" under the U.S. Marine Mammal Protection Act (see *What is 'take'?* and *What federal and international environmental laws protect whales?*). In addition, determining whether death was caused by human interaction can inform our understanding of the causes of unusual mortality events (see *What are strandings and Unusual Mortality Events?*), as well as guide effective responses to those events. The examination for human interaction could include documentation of:

- **Scars and lacerations on the body:** Scars are observed on many marine mammals, and it is often possible to determine whether they are due to human interaction. For example, when entanglements occur, there are regions of the body where gear tends to accumulate, including around the pectoral fins (fins on the side of the body), across the blowholes or top of the back, and around the spine just before the tail begins. Marks and scars in these regions, especially if they look like rubs or abrasions, are almost always due to entanglements in fishing line. If a vessel strike involves a propeller, it can be easy to determine if the skin is broken. The scar looks like an accordion fold along the body of the animal. Scientists are sometimes able to use the distances between propeller scars, the angle of intrusion, and the depth of cut to infer the size and possibly the speed of the vessel that struck the animal. Importantly, scientists can also sometimes determine if scarring occurred before or after death, based on internal examinations and bruising.
- **Internal injury:** If a full necropsy is conducted (see biological sampling, below), biological samples and professional assessments are typically conducted that focus on areas of suspected human interaction. This could include regions of the body with evidence of blunt force trauma (e.g., bruising or pooling blood, cracked or broken bones), material in the body (e.g., embedded lines, plastic or other debris), or areas identified by external scarring and/or lacerations. If a full necropsy is not conducted, some samples in these regions may still be taken to support the analysis in determining whether human interaction was a cause of death.

Measurements and documentation are a key part of the preliminary analysis. Photographs supplement the descriptions written in necropsy reports and can allow further analysis of any notable marks on the carcass. In addition, measurements are taken at standardized locations on the body, including measurements of blubber thickness along the body, estimated weight, and both length and width measurements. This initial external analysis, investigation of human interaction, and measurement protocol comprise the "Level A" data reporting; more details can be found in the Level A Examiner guide. The Level A data reports may be supplemented with further analyses, such as analyzing biological samples of the animal.

Biological Sampling

A necropsy comprises the cumulative measurements, observations, and samples obtained throughout the investigative process that aims to provide comprehensive results to determine the cause of a marine mammal mortality. Successful data collection is highly variable and depends on many factors. Importantly, the ability to conduct a thorough investigation is primarily dependent on the amount of decomposition of the animal. For example, many large whale species float after death due to the interior buildup of gases from decomposition, and can be subjected to rough weather and waves, predation from scavengers (e.g., sharks), and substantial sun exposure. Further, some animals may sink below the surface and begin decomposing and are only detected once emitted gas causes the animal to re-float, further influencing decomposition rate. Dead animal condition is determined by four codes (Code 2 through Code 5) that inform the type of sampling and analysis that is valuable and feasible for varying levels of decomposition. For example, an individual that is a Code 5 is essentially mummified or a skeleton, and the only valuable samples would include life history and genetics. In contrast, a fresh carcass, assigned a Code 2, can provide valuable samples for virology, histology, contaminants, and biotoxins.

Sampling options include the following, though this is not a comprehensive list:

- **Histopathology:** the microscopic examination of tissue for disease detection. Tissue samples are taken from multiple locations along and throughout the body.
- **Virology:** Testing for viruses is ideally conducted on the serum, lung, liver, spleen, lymph nodes, and brain, but additional samples are possible as well.
- **Microbiology:** These samples can be obtained with swabs or from tissue samples, and analyses provide information on bacteria and microbes.
- **Parasitology:** Any parasites can be sampled and stored for future identification and documentation. Parasites can also contain information vital to virology.
- **Contaminants:** Both human-produced toxic substances and natural toxins can be consumed by marine life and incorporated into their tissues. Marine mammals may have high levels of some contaminants, which can affect behavior or cause immune and endocrine issues. Contaminants can be sampled from blood, blubber, muscle, organs, skin, keratinized tissue, and bone.
- **Biotoxins:** These are naturally occurring toxins produced by marine algae (similar to harmful algal blooms that affect bivalves), which can accumulate in marine mammal tissues and have been attributed as the causes of a number of unusual mortality events in the past.
- **Life History and Genetics:** Information on age estimation, genetics, sex, reproductive status, trophic status, and habitat use can help inform changing trends or baseline physiological information, especially for species that are rarely sighted (e.g., beaked whales). Samples can include teeth, skin, stomach contents, gonads, blood, and bone.

Taxon-specific Necropsy Information

Best practices for conducting necropsies vary across different marine mammal species, including specific delineations of where to take measurements and collect samples. Information specific to small odontocetes, which includes dolphins, porpoises, beaked whales, pilot whales, and other similarly sized species, includes the types of stress-induced lacerations, bruising, and hormonal changes that may impact individuals that have stranded on shore. In addition, there are specific descriptions for internal organ sampling like the thyroid, lymph nodes, gall bladder, and reproductive tract for both male and female individuals. The marine mammal necropsy guide provides information on determining body condition for strandings responders and field biologists, as this can be difficult to assess for different types of marine mammals. The specific locations for sampling and measurements are given, as well as descriptions of typical and atypical markings on the outer body.

Large whale necropsies and mass strandings require substantial coordination, planning, and personnel management. Some strandings response organizations require federal training on the Incident Command System[44] typically used by multiple branches of the government for emergency planning and response and recovery efforts. The ability to fund such substantial and thorough necropsies in a timely manner (ideally within 48 hours of a stranding) is species-specific and depends on the status of the species under the Endangered Species Act, as well as whether an unusual mortality event is in process for the species/location where the stranding occurred (see *Who funds necropsies?*). Ultimately, the ability to conduct such a massive operation depends on funding, personnel, location, and timing. Waste disposal can also be an issue, as animals may be large; options include surface decay, beach burials, offshore dumping, land filling, composting, and incinerating.

Key personnel for large whale necropsies include off- and on-site coordinators, necropsy team leaders, photographers, cutting crews, sampling teams, and scribes to record all information. Site safety is the most important component of large whale necropsies. All personnel meet prior to the necropsy to cover personnel safety issues, which may include operating around large equipment, knives, chemicals, large body parts, and uneven shorelines, and use of proper personal protective equipment. More details on responding to large whales and mass strandings can be found in the MMSHRP Best Practices.

Post-necropsy Analysis

Though necropsy teams may have a comprehensive understanding of the causes and drivers of strandings, the results of specific cases are rarely immediately available. Preliminary information based on visual examination may provide some insight, but after samples are collected and the individual is disposed of, samples are sent to respective diagnostic laboratories and results can take weeks or months to obtain. In addition, whether a mortality was caused by anthropogenic impacts will be based on input from multiple individuals who are experts in marine mammal strandings. Once the necropsies are complete, reports are finalized and if there are determinations of anthropogenic causes of mortality, these may be used to inform estimates of population-level impacts and unusual mortality event determinations. The outcomes of necropsies are also used in conjunction with other datasets such as federal, academic, and public reporting to determine levels of mortality and serious injury under the U.S. Marine Mammal Protection Act and are reported in marine mammal stock assessment reports.[45] Level A data is considered public information and may be released upon written request from NOAA Fisheries, whereas sharing of necropsy results and diagnostic testing data (also known as Level B data) is at the discretion of individual stranding network participants that collected and analyzed the data.[46] See *Are necropsy reports publicly available?*

For More Information

- NOAA frequent questions on necropsies: https://www.fisheries.noaa.gov/national/marine-life-distress/frequent-questions-necropsies-animal-autopsies-marine-mammals
- Marine mammal necropsy: An introductory guide for strandings responders and field biologists: https://darchive.mblwhoilibrary.org/entities/publication/7701ada6-8af9-5c36-923b-bc44bc718183

[44] More information on the Incident Command System: https://training.fema.gov/is/courseoverview.aspx?code=IS-100.c&lang=en

[45] NOAA marine mammal stock assessment: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock

[46] NOAA FAQs: https://www.fisheries.noaa.gov/national/marine-life-distress/frequent-questions-necropsies-animal-autopsies-marine-mammals#how-long-does-it-take-to-get-results-from-necropsies?

- Information on the Marine Mammal Health and Stranding Response Program: www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-health-and-stranding-response-program
- NOAA FAQ on strandings and stranding response: www.fisheries.noaa.gov/insight/understanding-marine-wildlife-stranding-and-response
- NOAA examiner's guide: https://media.fisheries.noaa.gov/2021-07/EXAMINERS%20GUIDE_2024%20FINAL.pdf

Who funds necropsies?

- Necropsy costs are typically covered by the individual stranding network organization that conducts the necropsy (e.g., non-profit organization, academic institution, local, tribal, state or federal government agencies). However, such organizations may be eligible for monetary support through the competitive John H. Prescott Marine Mammal Rescue Assistance Grant Program through the federal government.
- The federal government distributes several million dollars per year to support recovery and data collection of marine mammals, including necropsies. In 2023, over $4 million was distributed through the Prescott Grant Program (total amount varies annually as appropriated by Congress). As of 2023, Congress limited these grants to a maximum of $150,000 per organization per 12-month period (the average award in 2023 was $81,425). There is a supplementary federal fund distributed during Unusual Mortality Events (UMEs), when necropsies may be conducted more frequently or thoroughly. There are also non-federal funding sources, such as states, non-federal grants, and private individual or organization donors.

Detailed Answer

The cost of necropsies, specifically large whale necropsies and response to mass stranding events, can be very high, and includes costs of personnel, heavy machinery, and carcass disposal, among other things (see *How are necropsies conducted?*). Necropsy costs are typically covered by the individual stranding network organization that conducts the necropsy, and organizations may include non-profit organizations, academic institutions, or local, tribal, state, or federal government agencies. These organizations can apply for federal funding to support necropsy activities and as members of the NOAA Stranding Network, organizations are eligible to apply for annual federal funding through NOAA Fisheries from the John H. Prescott Marine Mammal Rescue Assistance Grant Program.[47] This program was established as an amendment to the Marine Mammal Protection Act in 2000 and recently has provided approximately $2.7–3.8 million annually (2016–2022) for the recovery or treatment of marine mammals, as well as the collection of data from living or dead-stranded marine mammals, including conducting necropsies[48]. From 2001–2023, NOAA Fisheries awarded more than $75.4 million in funding through 839 competitive grants to stranding network organizations[49]. In 2023, NOAA Fisheries made 50 funding awards to 21 organizations. As of June 2024, funding for future years is uncertain.[50]

Supplemental federal funding is available during active Unusual Mortality Events (UMEs; see *What are strandings and Unusual Mortality Events?*) through the Marine Mammal Unusual Mortality Event

[47] John H Prescott Marine Mammal Rescue Assistance Grant Program: https://www.fisheries.noaa.gov/grant/john-h-prescott-marine-mammal-rescue-assistance-grant-program

[48] The amount of money allocated per fiscal year is subject to change per legislative actions including appropriations.

[49] NOAA Stranding Network organizations: https://repository.library.noaa.gov/view/noaa/50149

[50] Congressional budget: https://www.commerce.gov/sites/default/files/2024-03/NOAA-FY2025-Congressional-Budget-Submission.pdf

Contingency Fund,[51] established in 1992. This fund permits the federal Marine Mammal Health and Stranding Response Program to acquire private donations to support the response and investigation into active UMEs. This fund may be distributed to stranding network partners as a reimbursement for responses during UMEs and specifically covers caring for and treating live-stranded animals, the collection and processing of live-animal and necropsy samples, analyses by diagnostic laboratories, and the collection of marine mammal health data.

In addition to federal funds, response organizations are also typically funded by non-federal sources, including state funding, local government funding, and contributions from private donors or organizations. For example, the state of Massachusetts has funded multiple organizations to increase support for stranding investigations, rescue and rehabilitation, and to support responses to large whale strandings, which require substantial time, effort, and personnel. This funding includes support for longer-term research on topics such as vessel strike avoidance, veterinary interventions, and reduction of marine mammal entanglement in lines, cables, or fishing gear. In addition to direct funding, local governments provide support via local infrastructure and response (e.g., fire departments). State-wide support initiatives such as the Conservation License Plate in Massachusetts can support stranding response and necropsies.[52] As many stranding network organizations are non-profits and non-governmental, direct donations are also a component of their funding.

For more information

- NOAA Fisheries' Marine Mammal Health and Stranding Response Program: www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-health-and-stranding-response-program
- National Marine Mammal Entanglement Response Networks: https://www.fisheries.noaa.gov/national/marine-life-distress/national-marine-mammal-stranding-response-network

Are necropsy reports publicly available?

- The public accessibility of necropsy data varies by type of information.
- Basic information on the stranding event, such as date and location, is publicly available upon written request to NOAA Fisheries.
- Public access to more detailed data, such as the animal's life history and the results of tissue or sample analysis, is highly variable, as it is dictated by the specific stranding network participants that conducted the necropsy. However, following the passage of the Marine Mammal Research and Response Act in 2022, a web portal (the "Marine Mammal Health MAP") is currently under development to collate and publicly share some necropsy and analytical data from future strandings.

Detailed Answer

The public accessibility of information from necropsy reports varies by data type. The information obtained in a necropsy is broken down into Levels A, B, and C (see *How are necropsies conducted?*). Level A data include basic information on the stranding event, such as date, location, general information about

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[51] Marine Mammal Unusual Mortality Event Contingency Fund: https://www.fisheries.noaa.gov/national/marine-life-distress/marine-mammal-unusual-mortality-event-contingency-fund

[52] Massachusetts Whale License Plate Program: https://www.mass.gov/guides/massachusetts-right-whale-roseate-terns-conservation-license-plate

the animal, and results of the stranding event (e.g., carcass disposal)[53]. Level A data are public information that can be accessed by written request to NOAA Fisheries.[54] Level B and C data are additional information obtained from a stranding event and the associated individual(s). This may include the life history of an animal (e.g., historical sightings, reproductive status) and/or the results of any tissue or sample analysis conducted as part of the necropsy. These data are not required to be collected from every stranded animal, and the amount of detail obtained and reported may vary based on species, level of examination, decomposition level of the dead animal, available funding for conducting analyses and writing summary reports (most stranding network organizations rely on outside funding) and other factors. Public sharing of this information is currently dependent on the stranding network participants that collected and analyzed the data, and therefore the public accessibility of these data is highly variable. For more information on organizations that are part of the stranding network, see *Who funds necropsies?* The list of organizations receiving federal funding is also publicly available.[55]

Until recently, the only federally mandated centralized resource for stranding data was via requests to NOAA Fisheries for Level A data. In December 2022, however, Congress enacted the James M. Inhofe National Defense Authorization Act, which includes the Marine Mammal Research and Response Act (MMRA). The MMRA calls upon NOAA to establish a centralized database for stranding and related health information (specifically Level A, B, and C data) and to make it publicly accessible through a web portal. Supplemental Level B and C data that are collected will be required to be shared, including weather and tide, body measurements (i.e., morphometrics), histopathology, and toxicology, as well as virology and parasitology. The Marine Mammal Commission[56] has been a proponent of this database, called the "Marine Mammal Health Monitoring and Analysis Platform",[57] which is currently under development with planned availability in 2026. Importantly, new data sharing requirements will only apply to future strandings and necropsy data, not past events. In addition, there is a 2-year data "embargo" within the portal before making information publicly available to allow stranding network members to analyze and share the data they have collected (16 U.S.C. § 1421a Section 402d2B). This means that public visualization of Level B and C data is not likely to be available for several years following a particular stranding event. However, until the database is operational, Level A data can be requested by contacting NOAA Fisheries, and several data visualization efforts for Level A data are underway.

Offshore Wind Development Process

What are the major components of an offshore wind farm?

- Offshore wind farms are typically comprised of turbines, whose rotors convert mechanical energy from wind into electrical energy, and an offshore substation, which are linked to each other by a network of electrical cables. The electricity is transported onshore via export cables (which are typically buried in the seafloor) so that the energy can be integrated into the electrical grid.

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[53] Information about Level A data: https://www.fisheries.noaa.gov/national/marine-life-distress/level-data-collection-marine-mammal-stranding-events

[54] National Stranding Database public access information: https://www.fisheries.noaa.gov/national/marine-life-distress/national-stranding-database-public-access

[55] John H Prescott Marine Mammal Rescue Assistance Grant Program: https://www.fisheries.noaa.gov/grant/john-h-prescott-marine-mammal-rescue-assistance-grant-program

[56] Marine Mammal Commission: https://www.mmc.gov/priority-topics/marine-mammal-health-and-strandings/

[57] Marine Mammal Health MAP: https://www.mmc.gov/priority-topics/marine-mammal-health-and-strandings/marine-mammal-health-and-monitoring-analysis-platform-marine-mammal-health-map/

- Turbines can either have fixed foundations, in which the foundation is driven into the seabed, or floating foundations, which have a series of anchors attached to the foundation via mooring lines. Floating turbine designs are newer and are generally deployed in much deeper waters (50–300 m, or 164–984 ft).

Detailed Answer

Offshore wind farms comprise a network of offshore structures that are linked to each other by a network of array cables, and to onshore connection sites by an export cable that is typically buried in the seafloor. Offshore structures primarily include substations, which are platforms that collect turbine-generated power and prepare for the transmission of power to shore, and turbines, which are the quintessential structures that rotate to harness and convert mechanical energy of wind into electrical energy (NYSERDA OSW101; Figure 4). The electricity generated by the turbines is transported to shore via export cables to an onshore substation, where the energy is integrated into the electrical grid (Figure 5).

Fixed foundation turbines comprise a number of important parts (Figure 4), including the turbine foundation, which is driven into the seabed. Scour protection prevents erosion of the seabed around the foundation. A transition piece connects the foundation to the tower, which extends skyward from the sea surface and supports the rotating pieces of the structure.[58] There may also be a work platform that sits

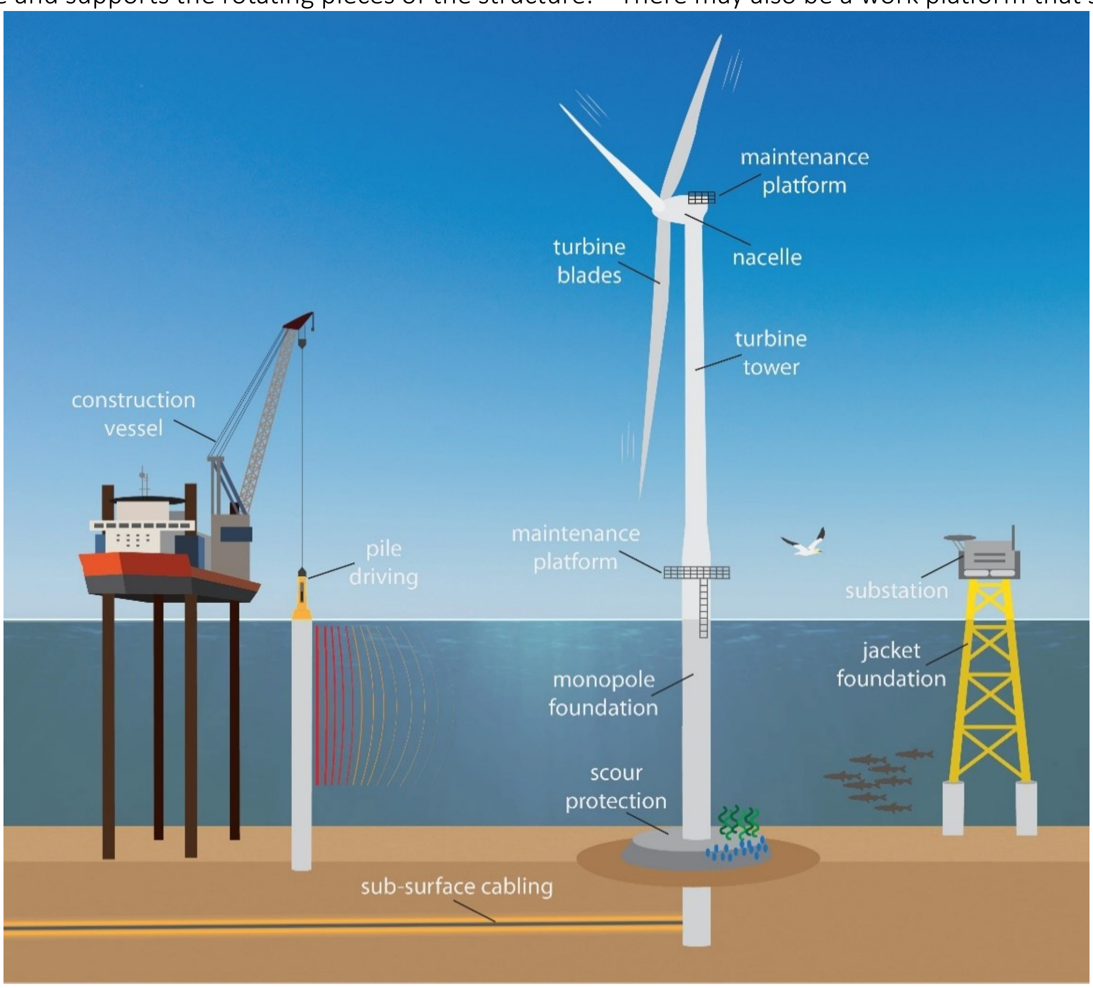

Figure 4. Components of an offshore wind farm. Source: Biodiversity Research Institute.

[58] More information: www.wind-energy-the-facts.org/offshore-support-structures-7.html

between 0–30m (0–98 ft) above sea level on the tower, and includes handrails, a boat landing and ladders, and other equipment required for maintenance. The nacelle is on top of the tower and houses the components that transfer mechanical power from the rotating hub and blades into electrical energy, and also has a platform for maintenance purposes. The blades capture wind energy and extend from the hub, which houses the system that controls blade pitch and rotation speed.

Importantly, turbines and offshore substations have typically been secured to monopile foundations that are installed to the seafloor through pile driving. However, there are a range of other foundation types, such as suction bucket and gravity-based foundations (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*), whose use typically depends on the seabed substrate, water depth, supply chain availability, and other factors. Floating offshore wind turbines are much newer, and there are several designs in use at pilot projects around the world; currently, the largest floating offshore wind farm consists of 5 turbines off the coast of Scotland.[59] Floating turbines include in-water structures of various kinds that support the tower and are connected to large cabling systems that are anchored to the seafloor. While traditional turbine designs can be installed in <50 m (164 ft) of water, and are typically installed in <30 m (98 ft) of water, floating wind turbines can be deployed in deep water regions up to about 300m (984 ft) in depth (Lin et al. 2021) that would otherwise be

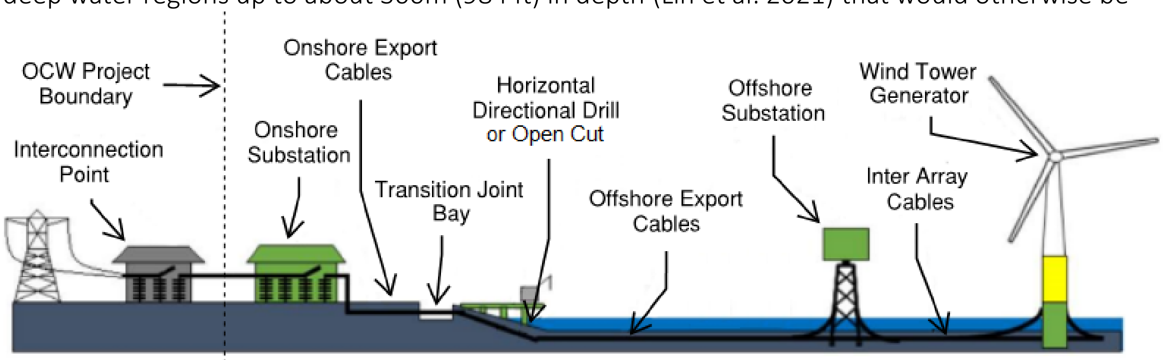

Figure 5. Diagram of main offshore wind project components. Source: HDR (https://media.fisheries.noaa.gov/2022-03/OceanWind1OWF_2022_508APP_OPR1.pdf).

inaccessible (e.g., most of the Gulf of Maine and U.S. Pacific coast, as well as areas farther offshore of the U.S. Atlantic coast).[60]

Offshore wind farm footprint and turbine sizes can vary greatly. As turbines increase in size, the energy capacity per unit of footprint is increasing (Wiser et al. 2023). Turbine capacity, blade diameter, and height of the structures have all increased steadily in the last 20 years, both on land and in marine environments, which increases efficiency of energy generation and influences the potential effects on wildlife and the marine environment. In addition, the cost per unit of energy typically decreases as the offshore wind farm size increases, driving expansion of offshore wind farms (Shields et al. 2021). The configuration and design of a particular wind farm will be site-specific, depending on physical characteristics of the site, available technologies and components, and other factors.

[59] Hywind Scotland: www.equinor.com/energy/hywind-scotland
[60] More information: http://www.nyserda.ny.gov/offshorewind

For More Information

- NYSERDA Offshore Wind 101: https://www.nyserda.ny.gov/All-Programs/Offshore-Wind/About-Offshore-Wind/Offshore-Wind-101
- Ørsted Offshore Wind Farm Construction Video: https://www.youtube.com/watch?v=3bntCXP8Yic
- Crown Estate Guide to an Offshore Wind Farm: https://www.thecrownestate.co.uk/media/2861/guide-to-offshore-wind-farm-2019.pdf

What are the potential effects of offshore wind development on whales?

- The main ways that marine mammals may be affected by offshore wind development are via (1) underwater sound; (2) vessel interactions; and (3) changes to habitat and prey. The offshore wind industry follows a stringent federal permitting process to minimize and mitigate marine mammal disturbance.
- The main sources of offshore wind-related sounds are geological and geophysical surveys (during site assessment of wind energy areas) and installation of wind turbine foundations (during construction). Operating turbines also emit low levels of noise into the water column. Site assessment surveys for offshore wind differ from oil and gas in that they do not employ the deeper penetration survey equipment used by oil and gas for estimating oil reserves. The equipment used for offshore wind development produces sounds of much lower volume and at high frequencies often above the hearing range of baleen whales.
- All vessels operating on the water pose a potential risk of vessel collisions to whales. Vessel strikes are thought to be the cause of many of the large whale strandings in New York and New Jersey in 2023 and are one of the major drivers of the decline of the endangered North Atlantic right whale. Offshore wind development is subject to stringent requirements to reduce risk of vessel collisions for marine mammals, primarily via vessel speed restrictions that require offshore wind industry vessels to travel under 10 knots (11.5 mph).
- Introducing offshore wind structures into the environment could change the abundance, distribution, and composition of marine mammal prey (e.g., via artificial reef effects), influence hydrodynamic processes, and potentially alter fishing patterns around the structures. These changes may alter where, and how, marine mammals use the habitat in and around offshore wind farms, though it is unclear the degree to which changes will occur or if they will positively or negatively affect whales.

Broad Answer

The primary factors associated with offshore wind development that may affect whales include underwater sound, vessel activities, and habitat change. Offshore wind development introduces a variety of sounds into the environment, particularly during construction, as well as additional boat traffic during construction, operations, and maintenance activities. In addition, offshore wind development could lead to changes in the habitats around offshore wind farms, which may result in either positive (e.g., creating of artificial reefs) or negative change (e.g., effective habitat loss). The potential impacts to individuals and populations from each of these changes will depend on multiple factors, including behavior, life history, population size, and habitat use.

Though there has been substantial research on certain taxa, effects, and stressors, not all taxa and regions have been thoroughly studied. Our knowledge of offshore wind effects is limited to regions where development has occurred (e.g., Europe) and impacted taxa in those regions (e.g., primarily harbor porpoise and seals). Most of the understanding of offshore wind effects on baleen whales in the U.S.

comes from thorough research on other anthropogenic activities, such as offshore oil and gas exploration and extraction, shipping, and naval activities, but only some components of these activities are relevant to assessing impacts of offshore wind development. Ultimately, the stressors that could cause death or serious injury to marine mammals during the development phases of offshore wind (e.g., ship strike or entanglement), are well understood, and mitigation measures are currently in place to help address these stressors. However, we are faced with shifting baselines due to the impacts of climate change and other long-term ecosystem changes. As we begin to understand these climate-driven effects, challenges remain in predicting how climate change influences the distributions, phenology, and abundance of marine mammals and more work is needed to help disentangle potential effects of offshore wind development from climate-related effects.

Acoustic Effects

There is a lot of research into the effects of anthropogenic sound on marine mammals, though it is important to note that impacts may not necessarily be transferrable between regions, species, or types of sound. The ocean environment is noisy, comprised of both natural (biological and physical) and anthropogenic sounds. Marine mammals use sound to communicate, to feed, socialize, and assess their environment, and certain types of anthropogenic sound impact marine mammal hearing and behavior. Marine mammals may suffer acute impacts, such as injury or death, if they are close to a harmful sound source, or may change their behavior or move away from a distant or less harmful sound source. Marine mammal hearing sensitivity and recovery from sound depends on the species, environment, and characteristics of the sound (e.g., volume, frequency, duration). Sound is expected at all steps of offshore wind development in varying amounts, though due to the above-mentioned factors, only some species or behaviors may be affected.

During pre-construction, underwater acoustic equipment is used to produce high-resolution maps of the seafloor and shallow sediments during the planning and assessment phase of development. While the seafloor mapping process for offshore wind is somewhat similar to that used for oil and gas exploration, the acoustic equipment used in oil and gas exploration to penetrate deep below the seafloor to search for oil and gas deposits produces much louder, lower-frequency sounds (see *How does sound produced from offshore wind development compare with other industries?*). Oil and gas exploration activities have demonstrated serious impacts to many marine mammal species from use of the deeper penetration survey equipment. In contrast, the equipment used for the mapping process for offshore wind are only to characterize the ocean bottom and shallow sediments. Most sound generated by these offshore wind activities are not expected to affect large whale species because they are low-volume and high frequency, often above the hearing range of baleen whales. Some sound emitted could potentially cause behavior changes in small cetacean and toothed whale species (see *What are the effects of anthropogenic sound on marine mammals?)*, though measures are in place to help mitigate those effects. Furthermore, there is no evidence of injury from offshore wind mapping activities in any marine mammals.

Sound generation during construction will likely have the greatest acoustic impact on marine mammals. Installation of fixed offshore wind structures on the sea floor (e.g., monopiles; see *What are the major components of an offshore wind farm?*) commonly involves a process called pile driving where a large hydraulic hammer drives posts (or piles) into the seabed, which emits loud sounds that carry great distances. If marine mammals are close to the pile driving activity, they could potentially experience temporary or even permanent hearing damage. At greater distances, it is thought that such sounds may interfere with communications during feeding, socializing, and nursery activities, or cause animals to avoid the area (e.g., displacement) which may be temporary or longer-term. Effects of sound vary by species (based on hearing capabilities) as well as the characteristics of the sound. However, a range of mitigation measures are available to reduce the effects of sound produced by pile-driving (see *What mitigation* *measures are available to avoid or minimize offshore wind effects on marine mammals?* ; *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*).

During the 30-year operational period of offshore wind farms, the sound produced by turbines is unlikely to reach levels that would significantly impact marine mammals but could result in a behavioral response for individuals close to turbines. As turbine size increases, so does operational sound which may increase the distance at which sound is detected by large whales. It is important to point out that we presently lack evidence on the effects of operational sound on large whales because existing studies from Europe have focused primarily on harbor porpoises and seals, and different marine mammal groups use and communicate with sound in very different ways.

Finally, all stages of offshore wind development and operations result in increased vessel traffic, which will increase vessel sound in the area, which could exacerbate the masking of sounds produced by marine mammals that already occurs due to existing vessel traffic (see *What are the effects of anthropogenic sound on marine mammals?)*. Technologies to reduce vessel sound are on the horizon, which may help mitigate this problem.

Vessel Strike Risk

Vessel strike risk is a great concern for marine mammals globally. Vessel traffic is increasing, in large part driven by the shipping industry. Vessel strikes are thought to be the cause of many of the whale strandings that occurred in New Jersey and New York in 2023, with recent federal data indicating that generally, high-density vessel traffic areas in approaches to major commercial ports pose the greatest risk of vessel strike mortalities (see *What factors influence vessel strike risk for large whales?*). Vessel strikes are also a leading driver of the population decline of North Atlantic right whales.

Offshore wind is expected to further increase vessel traffic, though it contributes a small part of total vessel activity globally, with offshore wind vessel activity currently accounting for about 2% of tracked vessel traffic in U.S. Atlantic waters from North Carolina to Southern New England[61] (see *How much vessel activity is expected from offshore wind development and what does that mean for strike risk to whales?*). Vessels operating at high speeds (>10 knots [11.5 mph]) have a significantly higher risk of causing death or injury to marine mammals upon colliding, and most current restrictions for vessel traffic operate on the premise that "speed kills". Offshore wind development is subject to stringent requirements to reduce the risk of vessel strike, including vessel speed restrictions, observers on vessels, passive acoustic monitoring, reporting when whales are sighted in an area, and other measures to reduce risk of collisions for marine mammals (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*).

Habitat Change

Marine mammals have large food requirements for migration, reproduction, and thermoregulation in cold ocean environments, and are therefore sensitive to changes in their habitats and prey. Introducing offshore wind structures into the environment could change the abundance, distribution, and composition of prey (e.g., reef effects), influence hydrodynamic processes, and potentially alter fishing patterns around the structures. Cabling introduces electromagnetic fields which may also influence prey distributions on or near the seafloor. These changes may alter where, and how, marine mammals use the habitat in and around offshore wind farms, though it is unclear whether changes would positively or negatively affect whales. There are other threats to marine mammals in busy coastal ocean environments,

[61] ACP Whale Fact Sheet: https://cleanpower.org/wp-content/uploads/2023/02/ACP_WhaleFactSheet_230222.pdf

such as entanglement in fishing gear and risk of vessel strikes from other industries, so offshore wind-related changes to where and when marine mammals occur could also lead to secondary impacts from other stressors. Marine mammals also face changing conditions due to climate change, with regime shifts occurring in the Northwest Atlantic resulting in shifting resources. It will be challenging to disentangle the effects of offshore wind development on resource availability and habitat from climate-induced changes in these same variables.

Understanding and Avoiding Population–level Effects

Offshore wind energy development may introduce risks to marine mammals, but the overall importance of any effects depends on whether large whale populations are negatively impacted (e.g., through reduced birth rates or juvenile survival, or increased death rates). In general, anthropogenic effects may vary in spatial and temporal scale, so impacts occurring locally may not translate into population-level impacts. In addition, rare species and those with small population sizes (e.g., North Atlantic right whales) will be more sensitive to small changes in survival and reproductive success than more abundant species (e.g., humpback whales).

From the perspective of current federal regulations (e.g., Endangered Species Act, Marine Mammal Protection Act), the goal is to maintain viable populations by reducing anthropogenic impacts (see *What federal and international laws protect whales?*). Although a small amount of lethal or non-lethal impact to marine mammals may be permitted in certain circumstances, no impact that would jeopardize a population is currently allowed under the Marine Mammal Protection Act and no lethal take has been authorized for the offshore wind industry to date (see *What is take?*). Therefore, the offshore wind industry follows a stringent federal permitting process to minimize and mitigate marine mammal disturbance. Scientists understand the general impacts of sound, vessels, changes to prey, and other effects on marine mammals, though they are still working to understand the specific effects of offshore wind on large whales. The current scientific understanding is used to inform offshore wind development and mitigation planning.

Detailed answer

Offshore wind energy development may impact whales differently depending on their behaviors, life history, population size, and habitat use (Bailey et al. 2014). The current understanding of possible impacts to marine mammals includes acoustic harm or disturbance, vessel collision risk, and habitat alteration, with the potential for cumulative effects from offshore wind development and from existing sources. The ocean is already heavily impacted by human activities, including recreational and commercial vessel traffic, fishing, seismic surveys, and oil and gas development (Bailey et al. 2014), and it is important to consider offshore wind development in the context of an environment that is already under stress (NYSERDA 2019). The addition of offshore wind development to the marine environment could potentially result in minimal effects to marine mammals, as these species are already accustomed to habitats that are under substantial disruption from other human activities. Alternatively, effects from various stressors could be cumulative, wherein marine mammal populations that are already vulnerable may become more vulnerable due to compounding causal factors (e.g., fishing gear entanglements, vessel strikes, and offshore wind impacts; Williams et al. 2015).

The existing research on offshore wind impacts on marine mammals has been primarily conducted in Europe. Therefore, research questions have focused on taxa relevant to those regions, such as harbor porpoise and seals that inhabit European waters (Thomsen et al. 2006, Kraus et al. 2019). Initial assessments of offshore wind-related risk to large whales are primarily drawn from knowledge of effects from other anthropogenic marine activities, such as naval activities, offshore oil and gas development, and marine infrastructure developments like bridges. Recently collected data from new offshore wind construction in the United States is becoming available (Amaral 2021), however, and mitigation measures developed for offshore wind in Europe, such as bubble curtains (which prevent sound propagation during pile driving of turbine foundations), are being increasingly tested and used in the U.S. context. Nevertheless, we are faced with shifting baselines due to the impacts of climate change and other long-term ecosystem changes. We have already seen distribution shifts of marine mammals, including the North Atlantic right whale, as a result of oceanographic regime shifts (Davies et al. 2019, Meyer-Gutbrod et al. 2021, Thorne et al. 2022). In the case of North Atlantic right whales, warming waters in the Gulf of Maine and the western Scotian Shelf resulted in a shift in the distribution of foraging grounds to the Gulf of St Lawrence, which had knock-on effects for calving rates and increased exposure to vessel collision and entanglement (Meyer-Gutbrod et al. 2021). As we begin to understand these climate-driven effects, challenges remain in predicting how climate change influences the distributions, phenology, and abundance of marine mammals (Lettrich et al. 2023) and more work is needed to help disentangle potential effects of offshore wind development from climate-related effects.

Acoustics Effects

There is substantial research on the effects of anthropogenic sound on marine mammals, though the results of existing studies are not necessarily transferrable to other regions, species, or sound sources. Studies on large whales and offshore wind are lacking, because activities associated with offshore wind are only beginning in areas where large whales typically occur. However, no studies have linked behavioral responses due to offshore wind sound with any measurable population change in marine mammals (Bailey et al. 2014).

Sound can occur as ambient (i.e., background sound), a single event (e.g., underwater explosion), continuous sound (e.g., vessel sound, turbine operational sound), or pulsed events (e.g., sonar, pile driving). The propagation of sound throughout the marine environment is dependent on sound frequency ("pitch"), duration, regularity, and levels (i.e., volume), as well as habitat features (e.g., water depth or substrate type). Marine mammals use sound to source food and communicate, for mating purposes, and to understand their surroundings. Marine mammals may be influenced by anthropogenic sound in a number of ways, ranging from no effect to alterations of behavior that may directly or indirectly influence fitness (e.g., survival and reproductive success; see *What are the effects of anthropogenic sound on marine mammals?*). Certain sound events may cause a temporary shift in the hearing threshold (TTS) for marine mammals, similar to tinnitus, with recovery to baseline hearing levels within hours to weeks following exposure (Ryan et al. 2016), while continued accumulation of small amounts of sound exposure may be impactful over time. More injurious exposure (louder or accumulating over longer periods of time) can lead to a permanent shift in hearing abilities (PTS) from which the animal does not return to baseline hearing capabilities (Ryan et al. 2016). These sound levels may drive marine mammals to move away from the sound source or alter their behavior to minimize exposure. Many mitigation measures are also in place during offshore wind development to minimize the risk of exposure to sound levels that could cause either TTS or PTS (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*). NOAA has developed a set of guidelines for assessing the effects of underwater anthropogenic sound on the hearing of marine mammal species, which identifies thresholds (e.g., received levels) for acute, incidental exposure to underwater anthropogenic sound sources at which different marine mammal species are predicted to experience changes in their hearing sensitivity (either temporary or permanent; NMFS 2018). This guidance is the standard used by the offshore wind industry to assess potential noise exposure impacts.

Sound exposure from offshore wind energy development varies by development phase. During pre-construction, underwater acoustic devices are used to characterize the seafloor (and sometimes fish and zooplankton distributions) to inform siting of offshore wind turbines. These systems use relatively quiet sound to obtain high-resolution imagery of the composition of the seafloor, as well as some shallow geological features. They are much smaller in scale and less impactful than the low frequency, loud technology used to explore deep below the ocean crust for oil and gas deposits, which have notable measurable effects on many marine mammal taxa (Figure 6; Gailey et al. 2007, Castellote et al. 2012, Cerchio et al. 2014, Blackwell et al. 2015; see *How does sound produced from offshore wind development compare with other industries?*). Most of the sound frequencies emitted by equipment used in offshore wind geophysical and geotechnical mapping surveys are low volume and outside the frequency range where large whales have demonstrated impacts, so these systems are not expected to have any measurable effect on large whales. Some sound emitted could also potentially cause behavior changes in small cetacean and toothed whale species, though measures are in place to help mitigate those effects. There has been no evidence of injury of any marine mammal associated with the sound generated in offshore wind mapping and studies.[62]

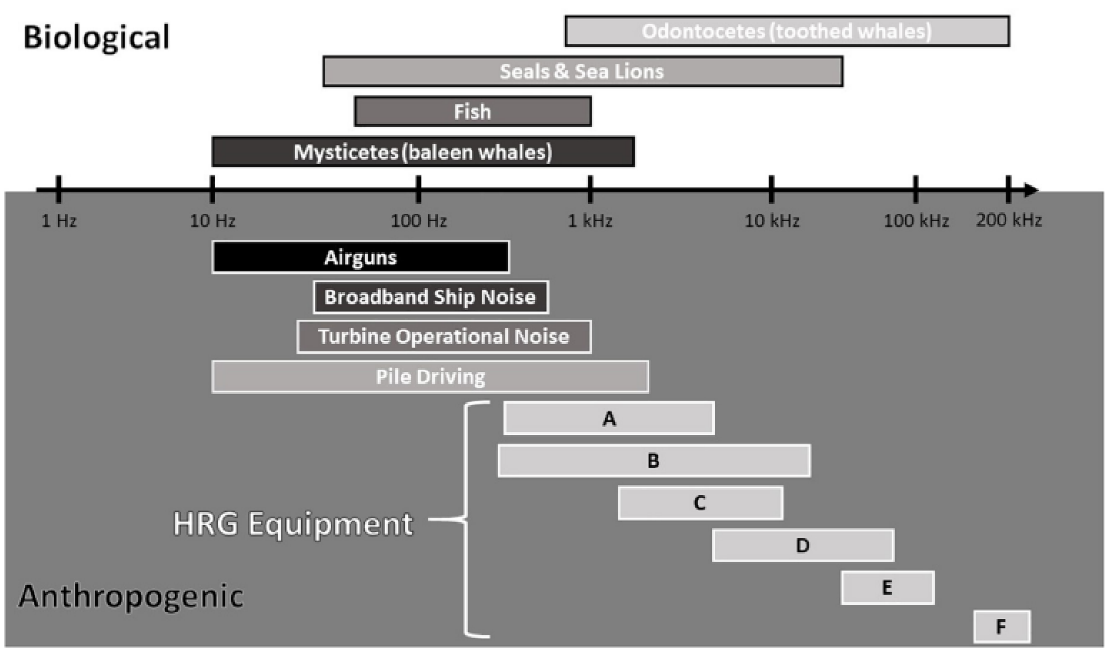

FIGURE 3 | This figure shows the frequency ranges over which groups of marine animals call (top) and the primary frequency ranges over which some anthropogenic sound sources (bottom) overlap. The frequency scale is on a logarithmic scale, expanding from 1 to 200,000 Hz. Mysticetes (baleen whales), such as the North Atlantic right whale, fin, sei, blue, humpback, and minke whale, produce low-frequency sounds, while odontocetes (toothed whales), such as the sperm whale, produce higher frequency sounds. Anthropogenic sound sources and primary frequency ranges are displayed on the bottom of the figure, with the bracketed boxes corresponding to the following high resolution geophysical (HRG) equipment sound sources: (A) Sparkers/boomers; (B) Non-parametric sub-bottom profilers; (C) Acoustic corers; (D) Acoustic positioning systems; (E) Parametric sub-bottom profilers; (F) Multibeam echosounders and sidescan sonar.

Figure 6. Frequency ranges of major human-caused sound sources in the marine environment and their overlap with the hearing ranges of marine animals. Airguns are used for oil and gas development; broadband ship noise refers to a range of vessel types from shipping and other industries. Pile driving occurs during offshore wind energy turbine construction as well as other anthropogenic activities such as wharf construction. Turbine operational noise and high resolution geophysical (HRG) survey equipment sounds are specific to offshore wind energy development, though similar sounds may in some cases also be produced by other anthropogenic activities. For more information, see *How does sound produced from offshore wind development compare with other industries?*. Figure source: Van Parijs et al. 2021 (https://www.frontiersin.org/articles/10.3389/fmars.2021.760840).

The construction phase will likely have the greatest acoustic effects on marine mammals. A process called pile-driving is commonly used to secure fixed offshore wind structures to the sea floor, which produces

[62] More information: https://www.noaa.gov/sites/default/files/2023-01/Transcript-011823-NOAA-Fisheries-Media-Teleconference-East-Coast-whale-strandings-508.pdf

impulsive, low frequency, and broadband sound (Madsen et al. 2006) that travels across large swaths of the ocean. The sound produced by driving the posts (piles) into the sea floor propagates through the water, sediment, and air. The average pile takes between 1–2 hours to install (Nedwell & Howell 2004, Siddagangaiah et al. 2022), though the process may occur over several weeks (Dähne et al. 2013). Since pile-driving requires very specialized vessels and equipment, and many offshore wind projects include dozens of turbines, pile driving activity for a single wind project will occur intermittently over periods of months or even years. Potential impacts from pile-driving could include permanent or temporary hearing damage for marine mammals in close proximity to the sound source, depending on the species (Thomsen et al. 2006, Bailey et al. 2014), behavioral avoidance, which could lead to displacement of animals from the location where sound is emitted (Bailey et al. 2014), or masking of calls (i.e. where sound is strong enough to interfere with detection of other sounds; Thomsen et al. 2006. For more information, see *What are the effects of anthropogenic sound on marine mammals?*). It is possible that the same sound could impair hearing near the source of the sound and disrupt behavior farther away from the source (Thomsen et al. 2006, Bailey et al. 2010). Disruptions have also been determined for other marine mammal species from pile driving activities of different industries (bottlenose dolphins, offshore wind development - Bailey et al. 2010; beluga whales, port infrastructure - Castellote et al. 2019; Hector's dolphin, wharf construction - Leunissen et al. 2019). Much of what we know about the effects of offshore wind-related sound to marine mammals comes from Europe where the harbor porpoise is a key study species; however, we can also learn the potential effects to large whales from other industries.

- ***Effects to hearing****:* Traditional pile driving involves multiple strikes over a given period of time, which amounts to a cumulative exposure for marine mammals, assuming their hearing does not fully recover between strikes and they remain in the area (Bailey et al. 2014). For example, for harbor porpoises, this could cause temporary hearing damage within about 10–50 m (33–164 ft) of the sound source, and permanent hearing damage within 5–20 m (16–66 ft) of the source (Thomsen et al. 2006, Bailey et al. 2014), though use of various mitigation measures (as well as potentially animals' own avoidance responses) will likely prevent animals from being present that close to pile driving activity, and other marine mammals species will have different distance thresholds (see Haver et al. 2018).
- ***Behavioral responses****:* One of the primary responses of marine mammals to sound is avoidance behavior. Pile driving sounds played, simulated, and conducted in real time in proximity to harbor porpoises indicate that there may be a behavioral response at distances of 20 km (12.4 mi) or more, though responses are variable (Carstensen et al. 2006, Tougaard et al. 2009). Documented displacement has been observed immediately after pile driving commences (Brandt et al. 2011) and can be long-lasting, with demonstrated avoidance effects of some offshore wind areas for up to a decade or more in harbor porpoises (Teilmann & Carstensen 2012). In another study of harbor porpoises around offshore wind farms in the north Irish Sea, however, the number of harbor porpoise in the offshore wind area decreased during construction, but the abundance before and after construction was the same (Vallejo et al. 2017). While we lack evidence of response distances to offshore wind development sound-generating activities for large whales, evidence from other industries suggest these species do respond. For example, humpback whales exhibited avoidance behavior from seismic airguns used in oil and gas development up to 4 km (2.5 mi) away (Dunlop et al. 2016). The response of animals at certain distances depends on a variety of factors, including the species' hearing capabilities, what behavior the animal is engaging in at the time of exposure, the sound level, sound propagation (i.e. how sound is dispersed throughout the environment as it moves away from the source), ambient sound levels, demographic characteristics such as sex, age, and presence of young, and individual-level

variation among animals, among other factors (National Research Council [U.S.] Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals 2003, Madsen et al. 2006a, Southall et al. 2008, Ellison et al. 2012). Avoidance of offshore wind project areas helps prevent auditory injury but can lead to effective habitat loss, which may negatively affect foraging success. Other behavioral responses may also occur in relation to sound from offshore wind development, including changes in diving, feeding, and movement patterns (Gomez et al. 2016).

- ***Masking****:* Pile driving, vessels, or other sounds that raise ambient sound levels in the ocean environment may "mask" or drown out important biological sounds, such as whale calls. Sound increases could impact marine mammal communication (Videsen et al. 2017) or could cause sublethal stress responses (Rolland et al. 2012). Pile driving sound occurs in the frequency range regularly used in communication between large whales (Kraus et al. 2019).

In addition to construction sound during turbine installation, vessels and operational turbines also produce underwater sound. Vessel traffic increases substantially over baseline levels during offshore wind construction, and to a lesser degree during pre-construction (e.g., survey vessels) and operations (e.g., maintenance vessels). This sound is not different in nature than that produced by other vessel activity in marine systems but will add to existing sound levels from other anthropogenic activities. The sound produced from offshore wind turbine operations, once construction is completed, is unlikely to reach dangerous levels for marine mammals (Tougaard et al. 2009), but could disrupt behaviors for individuals within close proximity of the pile (Koschinski et al. 2003, Thomsen et al. 2006, Madsen et al. 2006a). Based on measurements from relatively small (maximum power 2 megawatt) single turbines, sound produced during operations is of much lower intensity than during construction, though the duration of sound is expected to be almost continuous for the 30-year lifetime of offshore wind projects (Madsen et al. 2006a, Amaral 2020). Sound from operational turbines has been found at a U.S. offshore wind farm in Rhode Island to not significantly exceed background noise levels (Amaral 2020). The amount of operational sound scales with the size of the turbine, however, and larger turbines (on the order of 10 MW) are expected to be louder than small turbines, increasing the distance at which sound is detectable by marine mammals, and therefore may lead to a stronger behavioral response (Stöber & Thomsen 2021). The technological configuration of the gearing in newer turbines technologies could help offset some of these increased sound levels (Stöber & Thomsen 2021).

Vessel Collision Risk

The construction phase will likely have the greatest risk of vessel collision for marine mammals (Dolman & Simmonds 2010; see *How much vessel activity is expected from offshore wind development and what does that mean for strike risk to whales?*). Vessel strike risk has been documented as a primary causal factor for whale mortalities globally (Laist et al. 2001, Neilson et al. 2012, Schoeman et al. 2020), and has been specifically demonstrated for humpback and North Atlantic right whales in recent years (Rockwood et al. 2017, Brown et al. 2019, Garrison et al. 2022). Vessel strikes may occur with large vessels such as tankers and cargo vessels, as well as with smaller vessels (<65 ft in length; Stepanuk et al. 2021, NOAA 2022). Risk of lethality of collisions increases with increasing vessel speeds (Vanderlaan & Taggart 2007, Currie et al. 2017). Federal rulemaking to reduce the risk of vessel strikes of North Atlantic right whales sets a threshold for traveling at speeds of 10 knots (11.5 mph) or less during certain times of year within seasonal management areas (SMAs; see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?* for mor information on how SMAs are defined) to reduce collision risk and likelihood of serious injury or mortality if interactions occur (Vanderlaan & Taggart 2007, Wiley et al. 2011b, Conn & Silber 2013). The current North Atlantic right whale vessel speed rule applies to vessels

65 ft in length or greater (50 CFR § 224); however, NOAA issued a proposed rule in 2022 that would apply the 10 knot speed reduction to vessels that exceed 35 ft in length, with some exceptions (NOAA 2022b).

In addition to these general rules, offshore wind development is subject to more stringent requirements to reduce risk of collisions for marine mammals, including additional situations in which the 10 knot (11.5 mph) vessel speed restrictions apply, the use of observers on vessels transiting above 10 knots, passive acoustic monitoring, reporting of sightings, among other measures (BOEM 2021, 2022b, 2023). Offshore wind vessel fleet information is typically provided to the public by individual offshore wind developers as part of outreach to fishing communities and other mariners (for example, Vineyard Wind: www.vineyardwind.com/offshore-wind-mariner-updates; Ørsted: https://us.orsted.com/renewable-energy-solutions/offshore-wind/mariners, U.S. Wind: https://uswindinc.com/mariners/).

Habitat Alteration

Marine mammals, especially large baleen whales, require substantial consumption of densely schooling prey, such as krill and shrimp, or schooling fish, such as herring, sand lance, or anchovy (Kenney et al. 1997, Smith et al. 2015). Prey species may be affected by offshore wind development, including potential avoidance or attraction of prey to offshore wind structures (Bailey et al. 2014). Refugia can be developed as a result of artificial reef effects, i.e. where ocean life adheres to subsurface structures (e.g., mussels, tunicates) which can support locally dense regions of biomass. During operation of wind farms, the subsurface cables that transmit energy also emit electromagnetic fields, and some fish species are sensitive to these emissions (see *What are the effects of electromagnetic fields (EMFs) from offshore wind development on marine mammals and their prey?*). It is possible that these changes could impact the distribution and behavior of prey that inhabit sediments or water near the sea floor (Bailey et al. 2014, Nyqvist et al. 2020, Copping et al. 2021). In close proximity to cables, some animals have demonstrated behavioral responses, such as increased foraging and exploratory movements, though there is no evidence to date that these changes negatively affect animals.

It may be infeasible for some fisheries (e.g., large trawls) to operate in offshore wind areas, which could result in a refuge for fish species that would otherwise be subjected to fishing pressure (Bailey et al. 2014, Kraus et al. 2019). Offshore wind areas may likewise serve as safer areas for marine mammals, if some types of fishing and vessel traffic become less common (Kraus et al. 2019). Seals have been observed preferentially foraging around offshore wind foundations (Russell et al. 2014). Because marine mammals (as warm-blooded, highly migratory animals) have high caloric requirements, they may be negatively or positively impacted by the possible alterations to habitat that may occur with offshore wind operations. However, marine mammals are highly mobile and are typically capable of relocating or seeking alternative sources of food (Wiley et al. 2011a, Smith et al. 2015). Though it is possible these factors could affect marine mammals, any habitat alteration would need to occur at a scale that is relevant to impact marine mammals at both an individual and population level (e.g., by affecting animals' survival rates or reproductive success).

Interactive and Cumulative Effects

The impacts of the potential effects listed above depend on their cumulative, or overall, risk to large whale populations and the conservation status (e.g., abundance) of those populations. Individuals within a population may experience some level of disturbance, but the offshore wind industry must obtain permits through detailed federal processes intended to protect marine mammals, and there are mitigations in place to avoid lethal and sublethal damage to individuals and prevent any population-level effects (see the *Offshore Wind Regulatory Processes and Mitigation* section of this document).

When assessing the potential effects of offshore wind energy development on marine mammals, it is important to also consider potential compounding or interactive effects, particularly across regions and industries. For example, fishing exclusion zones have led to substantial increases in fishing pressures at the boundary of the protected region, which can influence the distribution and accumulation of fishing gear (Nillos Kleiven et al. 2019). If offshore wind development leads to changes in fishing patterns, this has the potential to also change the risk of whale entanglement with fishing gear. Though the specific effects of offshore wind development on large whales are still being studied, scientists have a good understanding of the general effects of sound, vessels, prey shifts, and other effects on marine mammals, all of which are being considered in offshore wind energy development and mitigation planning.

For More Information

- Detailed website on underwater sound, including information on how animals use sound and on sound effects to animals: https://dosits.org/
- NOAA Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): https://www.fisheries.noaa.gov/s3/2023-05/TECHMEMOGuidance508.pdf
- Transcript of NOAA Fisheries Media Teleconference on East Coast Whale Strandings, January 2023: https://www.noaa.gov/sites/default/files/2023-01/Transcript-011823-NOAA-Fisheries-Media-Teleconference-East-Coast-whale-strandings-508.pdf
- Offshore wind research briefs from the Pacific Northwest National Laboratory and National Renewable Energy Laboratory on vessel collisions, underwater sound, and habitat change: https://tethys.pnnl.gov/summaries/seer-educational-research-briefs

Does offshore wind energy development kill whales?

- There is no documented scientific evidence that offshore wind energy activities kill whales.
- While offshore wind energy development, like any marine development, has the potential to affect whales (see *What are the potential effects of offshore wind development on whales?*), the sounds produced during all phases (i.e., site assessment, construction, and operations) are insufficient to cause direct mortality. However, the sound emitted may impact hearing or behavior, and the build up of sound from a range of anthropogenic sources may lead to chronic effects. There are various mitigation measures in place to reduce risk of potential impacts from offshore wind-related sound (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*)
- Collisions are a concern for all vessels in the marine environment across industries. Vessel collisions have the potential to injure or kill whales. However, offshore wind vessels comprise a very small portion of all vessels in the marine environment, and they operate in a more precautionary manner to avoid the types of collisions that occur with other industries, which reduces this risk (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*).

Detailed Answer

There is no documented evidence that offshore wind energy development activities kill whales. Most offshore wind development activities in the U.S. Atlantic to date have been related to site characterization (pre-construction activities to determine where to place turbines and cables, to identify the types of sediments in the local seabed, etc.). NOAA Fisheries, which is responsible for managing and protecting whales in the United States, has indicated that, "there is no scientific evidence that sound resulting from offshore wind site characterization surveys could potentially cause mortality of whales. There are no known links between recent large whale mortalities and ongoing offshore wind surveys."[63] The

[63] NOAA FAQs: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales

geophysical and geotechnical surveys conducted prior to construction of offshore wind farms do generate sound. Some of these sound sources have the potential to disturb cetaceans, though many of the sound sources used for offshore wind surveys are considered "*de minimis*" and unlikely to do so (Ruppel et al. 2022). The sound from these surveys is very different from the sounds produced by seismic air guns used for activities related to oil and gas and tactical military sonar, both in terms of frequency and sound level (see *What are the potential effects of offshore wind development on whales?* for detailed sound frequencies from various anthropogenic activities). Lower levels of sound are emitted during offshore wind site characterization surveys and would not cause mortalities (Ruppel et al. 2022). There have been no strandings of any marine mammal associated with the types of equipment used in offshore wind surveys.[64] This is in contrast to other activities, where the use of air guns for offshore oil and gas exploration and active sonar used by the military have both been linked to negative impacts to cetaceans (Balcomb & Claridge 2001, Parsons 2017, Bernaldo de Quirós et al. 2019, Mooney et al. 2020, Ruppel et al. 2022 see *How does sound produced from offshore wind development compare to other industries?*). In addition, the offshore wind industry uses various mitigation measures, including dedicated observers on many vessels (see *What are Protected Species observers and what data do they collect about marine mammals?*), to reduce the potential impacts to marine mammals during site characterization surveys (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*).

Sound is also generated during offshore wind farm construction, particularly during turbine foundation and substation installation (e.g., pile driving). While this sound has the potential to affect cetacean behavior, it is not predicted to occur at levels that would cause mortalities. This sound could permanently or temporarily affect whale hearing capabilities if an animal is within close proximity to the pile-driving activity and does not move away from the activity. The exact distance at which sound affects marine mammals varies based on numerous factors, including the characteristics of the sound (e.g., duration, frequency, volume) and the environment, along with the species' hearing capabilities and diving behavior; this information is used to define mitigation zones to minimize marine mammal exposure to the sound. Odontocetes (i.e., toothed whales) are considered mid-frequency cetaceans and are more sensitive to pile driving sound than cetaceans that typically hear and use sound in lower frequencies (e.g., baleen whales), though both groups have the potential to be affected (see *What are the potential effects of offshore wind development on whales?*). NOAA has produced technical guidance (NMFS 2018) to predict how marine mammal hearing is affected by sound exposure. These characteristics, among other factors, are used to estimate the mitigation and monitoring zones during these sound-generating activities (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*). Sound from operational turbines is substantially quieter and typically does not significantly exceed background noise levels (Amaral 2020). While it is possible that these sounds could result in behavioral change in some circumstances, the scale of these potential effects is small (see *What are the potential effects of offshore wind development on whales?*).

The other main source of concern for whales in relation to offshore wind energy development is vessel traffic, which is a risk across all maritime industries. Vessel collisions can kill baleen whales, especially large vessels traveling at high speeds (Vanderlaan & Taggart 2007, Currie et al. 2017). Recent analyses and documented interactions between large whales and vessels suggest that smaller vessels operating at high speeds may also cause lethal injury (Stepanuk et al. 2021, NOAA 2022b). NOAA Fisheries instituted a vessel speed restriction rule in 2008 to specifically protect North Atlantic right whales, which states that all vessels 65 feet or longer must travel at 10 nautical miles per hour (knots) or less in certain locations along the U.S. Atlantic coast, and at certain times of year; these locations are termed seasonal

[64] More information: https://www.noaa.gov/sites/default/files/2023-01/Transcript-011823-NOAA-Fisheries-Media-Teleconference-East-Coast-whale-strandings-508.pdf

management areas (SMAs).[65] Voluntary dynamic management areas (DMAs) and slow zones are also designated when North Atlantic right whales are observed outside of the geographic extent or effective period of SMAs. DMAs are designated specifically when reliable sightings are obtained of three or more right whales within a 75 square nautical mile area (Silber et al. 2012), while the designation of a slow zone happens based on detections via passive acoustic monitoring. Mariners are encouraged to avoid these areas if possible, or to reduce speeds to 10 knots or less while transiting through these areas.

While the vessel speed rule was initially effective in reducing vessel strike risk to North Atlantic right whales, climate-driven shifts in the species distribution outside of the SMAs has caused the number of vessel strikes to again increase, and more information has become available on the lethal risk posed by vessels less than 65 feet in length (Garrison et al. 2022). These changes led NOAA Fisheries, in 2022, to announce proposed changes to the vessel speed rule to further reduce the likelihood of vessel collisions (NOAA 2022b). In the meantime, BOEM, the federal agency that oversees offshore wind energy development, already made most of these proposed rules mandatory for most offshore wind related vessels, ensuring that the offshore wind industry uses more protective measures for whales than any other anthropogenic activities in marine waters of the U.S. (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*). While the focus of these protections is often the endangered North Atlantic right whale, this also serves to benefit other marine mammals and sea turtles.

Offshore wind energy development increases vessel activity during construction activities by 6.82–36.41 vessel hours per month as compared to the preconstruction period (n=3 wind farms; Bishop 2024). During operation, vessel density decreases from the construction period and is only 2.52–4.98 vessel hours per month higher than pre-construction levels (Bishop 2024).

Offshore wind development projects are required to obtain authorizations from NOAA, called one-year incidental harassment authorizations (IHAs) or five-year incidental take regulations (ITRs) that are accompanied by a Letter of Authorization (LOA), for activities that could impact whales. The authorizations are required of any industry or individual that wishes to conduct an activity that could incidentally impact whales, including fisheries and other maritime users. However, these authorizations are only granted if the activities are likely to have no more than a "negligible impact" on the species or stock.[66] Under the U.S. Marine Mammal Protection Act (MMPA), energy infrastructure projects can apply for authorizations for incidental (e.g., non-intentional) harassment of marine mammals, where "harassment" is defined as any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal (Level A) or disturb a marine mammal by causing disruption of behavioral patterns (Level B; 16 U.S.C. §1362). Level A harassment only applies to the potential for "non-serious" injury.[67,68] NOAA Fisheries has stated, "NOAA Fisheries does not anticipate and has not authorized—or proposed to authorize—mortality or serious injury of whales for any wind-related action. Offshore wind developers have not applied for, and NOAA Fisheries has not approved, authorization to kill any marine mammals incidental to offshore wind site

[65] Seasonal Management Areas: https://www.fisheries.noaa.gov/resource/map/north-atlantic-right-whale-seasonal-management-areas-sma
[66] Incidental Take Authorizations under the MMPA: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act
[67] NOAA FAQs: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales
[68] More information on the MMPA: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-protection-act

characterization surveys or construction activities."[69] As of March 2024, over a dozen offshore wind projects have active IHAs for site characterization and five have active ITRs and LOAs for construction activities, resulting in a NOAA Fisheries determination of 'negligible impact,' with many additional past issuances for both site characterization and construction.[70] The IHAs and ITRs only consider take (see *What is take?*) from a single activity or project, rather than across projects, when determining a proposed action's negligible impact level. However, NOAA factors into their analysis both past and ongoing anthropogenic activities via their impact on the baseline (e.g., as reflected in the density, distribution, and status of the species, population dynamics, and other relevant stressors).[71]

Finally, while there have been recent unusual mortality events for several baleen whale species along the U.S. Atlantic coast (see *What are strandings and Unusual Mortality Events?* and *Why are baleen whales dying right now in the Northwest Atlantic and is this a new phenomenon?*), this pattern dates back to 2016, before most offshore wind energy activities began in federal waters. This was after the Block Island Wind Farm was already operational in Rhode Island state waters. The first site assessment plans in the Massachusetts/Rhode Island region were not approved until October 2017.[72] As such, current evidence suggests that these strandings are not connected to offshore wind development activities but rather relate to a combination of natural and anthropogenic factors, including increases in population size (humpback whales) and shifting prey and whale distributions inshore, leading to increased interactions with vessels (see *Why are baleen whales dying right now in the Northwest Atlantic and is this a new phenomenon?*).

For More Information

- NOAA FAQ on offshore wind and whales: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales
- Additional information on right whales and vessel strikes, including vessel speed rules: https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales#proposed-modifications-to-right-whale-speed-rule.

How much vessel activity is expected from offshore wind development and what does that mean for strike risk to whales?

- The contribution of offshore wind vessel activity to strike risk is generally considered to be very low both because of the small relative contribution of this industry to existing maritime vessel traffic, as well as the strict rules in place for offshore wind activities that are intended to reduce strike risk to whales (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*).
- Offshore wind development involves many kinds of vessels over the life of a wind farm, and vessel needs change during each project phase. Vessel activity typically peaks during wind farm construction and immediately subsides post-construction to near pre-construction levels.

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69 NOAA FAQs: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales

70 Active Incidental Take Authorizations: https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable#active-authorizations

71 More information on incidental take: https://www.federalregister.gov/documents/2023/07/26/2023-15817/takes-of-marine-mammals-incidental-to-specified-activities-taking-marine-mammals-incidental-to

72 Site assessment plan approval for OCS-A-0486: https://www.boem.gov/sites/default/files/renewable-energy-program/State-Activities/RI/SIGNED_BOEM-to-DWW_SAP-Approval-for-OCS-A-0486_101217-%281%29.pdf

- Offshore wind vessel activity is subject to mitigation and monitoring measures that are not required of other maritime activity, including enhanced speed reduction, dedicated observers, and near-real time passive acoustic monitoring, all of which lower the strike risk profile for offshore wind vessels relative to vessels from other industries.
- Mathematical models can assess strike risk related to offshore wind vessel activity using vessel- and species-specific data to represent real-world scenarios, which can be used to plan vessel activity that minimizes risk. As the offshore wind industry grows, it will be important to re-evaluate strike risk to whales and mitigate risk whenever possible.

Broad Answer

Quantifying strike risk to whales is challenging due to the diversity of vessel activities, species, and environmental conditions in areas where anthropogenic activities occur. Understanding offshore wind-specific strike risk is no exception. In general, the likelihood and severity of a vessel strike depend on the spatiotemporal overlap of both vessels and whales, as well as vessel and whale characteristics and behavior. Importantly, vessels and whales can exhibit a range of characteristics and behaviors making them either more or less likely to collide (see *What factors influence vessel strike risk for large whales?*). These factors are not exclusive to offshore wind development. However, to understand potential risk from this industry, we need to understand the number and types of vessels used during offshore wind energy development and operations.

Many different vessels are used during various stages of offshore wind energy development to support pre-construction surveys, construction, operations and maintenance, and decommissioning. Recent research to evaluate vessel density around U.S. offshore wind farms along the U.S. Atlantic Coast found no significant long-term change in vessel-hours around wind farm sites, but did identify temporary, highly localized increases in hours vessels spent around wind turbines during construction, which subsided immediately post-construction. It is important to note that offshore wind vessels are subject to more stringent vessel speed restrictions and other mitigation requirements to reduce strike risk compared with other maritime industries (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?).*

Complex analytical models can provide risk estimates when sufficient data about key factors influencing strike risk are available – vessel size and speed, species characteristics and behavior, etc. Using these models, strike risk related specifically to offshore wind vessel activity can be assessed based on individual vessel trajectories, which can then be aggregated to estimate risk at project or regional scales over time. Given existing mitigation strategies required for offshore wind vessels (including vessel speed restrictions and both observers and passive acoustics on vessels; see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*) and the small size of the offshore wind fleet in the U.S. (~2% of tracked vessels in the U.S. Atlantic), offshore wind vessel contribution to strike risk is generally considered to be very low, especially relative to other industries like shipping and fishing (*see What are the potential effects of offshore wind development on whales?*). Moreover, U.S. federal agencies have found "no known links between large whale deaths and ongoing offshore wind activities", including offshore wind vessel activity (see *Does offshore wind energy development kill whales?).* Nevertheless, it will be important to monitor increasing vessel activity as offshore wind expands and re-evaluate strike risk under changing maritime industry and ecological conditions.

Detailed Answer

Many aspects of maritime vessel activity are relevant for assessing the risk of collisions with whales. In general, the likelihood and severity of a vessel strike depend on the spatiotemporal overlap of both vessels and whales, as well as vessel and whale characteristics and behavior. Importantly, vessels and whales can exhibit a range of characteristics and behaviors making them either more or less likely to collide (see *What factors influence vessel strike risk for large whales?*). These factors are not exclusive to offshore wind development and apply to all sectors of maritime activity, including shipping, fishing, tourism, and other vessel uses. Offshore wind development in the U.S. is additionally subject to stringent requirements to reduce the risk of vessel strike, including vessel speed restrictions (which also reduce vessel noise), trained observers on vessels, passive acoustic monitoring, reporting when whales are sighted in an area, and other measures (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*), many of which go beyond requirements of other maritime industries.

A general understanding of the different phases of offshore wind vessel activity can help us qualitatively assess risk from an industry-specific perspective. Vessel activity from offshore wind development can consist of many types of vessels (Figure 7), and the numbers and kinds of vessels in use vary over the life of a project, which generally spans 30 to 40 years.[73,74] There are over 25 different types of vessels used in offshore wind development across construction, operations, and maintenance of a project.[75] Prior to

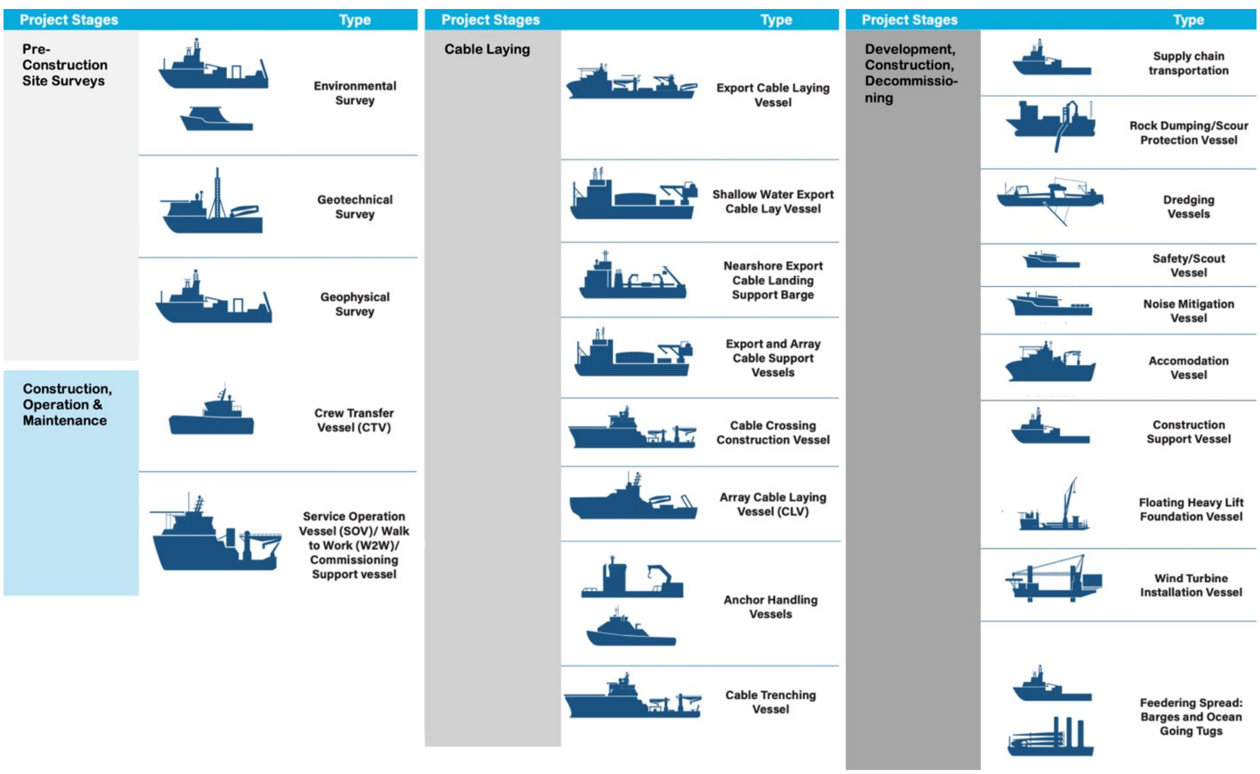

Figure 7. Types of vessels involved in the various project stages of offshore wind development. See ACP Fact Sheet: Offshore Wind Vessel Needs for more information.

[73] U.S. Coast Guard information on offshore wind support vessels: https://www.dco.uscg.mil/OCSNCOE/NME-Support-Vessels/Types/

[74] NYSERDA webinar overview of offshore wind vessel operations: https://www.youtube.com/watch?v=hSts27w9jfg&list=PLNs7tyvrkK1Vv06lE5zVgJpa64X619TEL&index=21

[75] American Clean Power Association, Offshore Wind Vessel Needs Fact Sheet: https://cleanpower.org/wp-content/uploads/gateway/2021/09/OffshoreWind_Vessel_Needs_240214.pdf

Post-construction, relatively few vessels are needed, primarily to transfer and house maintenance and inspection crews and to transport small equipment on a regular basis. Less frequently, a larger vessel may be required during operation for major component transport and repairs.[2] Finally, many of the same vessels used in the construction phase are repurposed for wind farm decommissioning (Gjødvad & Ibsen 2016). As part of outreach to the broader maritime community, offshore wind developers provide public updates on project-specific vessel activity where vessel inventories, locations, and descriptions can be viewed.[76,77,78]

Vessel Activity at Offshore Wind Farms

Recent research evaluated how vessel density around three U.S. wind energy areas changed over each project's development (Bishop 2024). The study included Block Island Wind Farm (BIWF; Rhode Island), Vineyard Wind I (VW1; Massachusetts), and Coastal Virginia Offshore Wind Pilot Project (CVOW; Virginia), which range in size, capacity, distance from shore, geographic region, and development timeline. Authors compared vessel density around each wind farm across pre-construction, construction, and post-construction phases (except VW1, for which construction was still underway at time of publication), as well as comparing the wind farms to other random spatial samples nearby, which served as controls. Vessel density was measured as vessel hours spent per month per square kilometer across all vessel types. In general, the greatest increases in vessel density around wind farms occurred during construction and were highly localized to areas adjacent to wind turbine installations (Bishop 2024). Specifically, vessel density increased on average by 7, 34, and 36 hours per month, respectively, for VW1, BIWF, and CVOW during construction. For BIWF and CVOW, these increases were offset by almost equivalent decreases post-construction (-29 hours/month for BIWF,-34 hours/month for CVOW), while VW1 was still under construction when the study was published. Average post-construction vessel density around wind farms was slightly higher than pre-construction density by 5 hours/month at BIWF and 3 hours/month at CVOW, but differences were not significantly different from zero. Moreover, similar pre- vs. post-construction patterns and vessel densities at nearby randomly sampled areas (n=14) over the same time periods suggest that these increases may have been driven by more general increases in vessel traffic across sectors, rather than specifically by offshore wind development. Findings from this study indicate that "any additional vessels put on the water due to wind farm construction are almost completely removed post-construction, and post- construction maintenance requirements do not cause a significant, lasting vessel presence" (Bishop 2024). Studies like this can help us identify specific locations and times (months, development phases) where vessel strike risk for whales may be elevated, but they do not explicitly consider whale exposure based on species distributions, characteristics, or behavior, which are essential for risk assessment. Furthermore, data limitations did not allow this 2024 study to assess vessel speeds or movement behavior, which are known to influence strike risk (*see* *What factors influence vessel strike risk for large whales?*).

Other sources also indicate the small proportion of overall maritime vessel traffic represented by offshore wind vessels (see *How does sound produced from offshore wind development compare with other industries?**)*. In 2023, offshore wind vessel activity accounted for only 2% of tracked vessel traffic in U.S. Atlantic waters from southern New England to North Carolina.[79] A 2022 report for NYSERDA indicated similarly low levels of vessel traffic associated with offshore wind development in New York state waters

[76] Vineyard Wind Mariner Updates: https://www.vineyardwind.com/offshore-wind-mariner-updates

[77] Orsted Resources for Local Mariners: https://us.orsted.com/renewable-energy-solutions/offshore-wind/mariners

[78] U.S. Wind / For Mariners: https://uswindinc.com/mariners/#1646151557145-48c13cbc-a071580c-6da8a6f3-61cd21b9-78713c5e-f4ab

[79] American Clean Power Association, Offshore Wind is Protecting Whales Fact Sheet: https://cleanpower.org/gateway.php?file=2023/02/ACP_WhaleFactSheet_230222.pdf

(Toilliez et al. 2022). Specifically, vessel traffic models estimated that annual increases in vessel traffic due to offshore wind construction and operations would account for about 0.5% (range 0-4% depending on location) of the overall projected increase in vessel traffic from 2017-2040 (Toilliez et al. 2022).

Given the diversity of vessel activities, marine mammal species, and environmental conditions in areas where offshore wind development occurs, assessing industry-specific vessel contributions to strike risk is challenging. One way of evaluating strike risk associated with offshore wind vessel activity involves using complex analytical models, which can quantify the probability of a vessel encountering an animal (i.e., encounter rate) while transiting to/from a wind farm and operating within a wind farm. The Bureau of Ocean Energy Management (BOEM) commissioned the development of an offshore wind industry-specific model, which calculates encounters per unit area by accounting for key vessel-related parameters known to influence strike risk, such as size, speed, draft (keel depth), and movement level (% time moving vs. stationary) (Barkaszi et al. 2021). Species-specific predictors for whales, such as body size, mean density and group size, activity (e.g., foraging, migrating, calf-care), swim speed, and depth-related metrics, are also included with an associated spatiotemporal component (month and region). Both vessels and animals can exhibit behaviors to avoid collision (i.e., aversion), so model users can incorporate the level of aversion to better assess when vessel-animal encounters are predicted to become actual strikes. Overall, models like this are useful for representing key elements of vessel strikes and can help quantify strike risk in a variety of highly specific scenarios and for defined offshore wind vessel trajectories. They do not, however, quantify strike severity or consequences (e.g., animal mortality vs. injury), nor do they include vessel noise predictors that may be relevant for strike risk. As of early 2025, there were no published examples of this model, as it was still under development with continued funding from BOEM.

Increased vessel density and presence around wind farms will also generate more underwater noise. Currently, however, the specific relationship between underwater vessel noise (intensity, duration, source, etc.) and strike risk to whales is not well characterized, and again, this is not specific to the offshore wind industry.

Given the small relative size of the offshore wind fleet in the U.S. and current mitigation measures, the contribution of offshore wind vessel activity to strike risk for whales is generally considered to be very low. To date, U.S. federal agencies have found “no known links between large whale deaths and ongoing offshore wind activities”,[80] including offshore wind vessel activity (see *Does offshore wind energy development kill whales?*). Nevertheless, it will be important to monitor increasing vessel activity as the footprint of offshore wind expands and re-evaluate strike risk under changing industry and ecological conditions at local and regional scales.

For More Information

- SEER Webinar #4: Electromagnetic Fields & Vessel Collision Effects on Marine Life from Offshore Wind (46:00-1:01:00): https://www.youtube.com/watch?v=b52qrn1hNM4
- NRDC Expert Blog - Reducing Vessel Strike Risk During Offshore Wind Operations: https://www.nrdc.org/bio/francine-kershaw/reducing-vessel-strike-risk-during-offshore-wind-operations

[80] NOAA Fisheries, FAQ Offshore Wind & Whales: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales#is-us-offshore-wind-development-linked-to-any-whale-deaths

What are the effects of electromagnetic fields (EMFs) from offshore wind development on marine mammals and their prey?

- Like existing submarine power cables and to a lesser extent telecommunication cables, electrical cables that carry power from offshore wind developments to shore produce electric and magnetic fields (EMFs) that some marine species may be able to detect.
- Marine mammals likely use Earth's magnetic field for migration, but they are not known to detect electric fields. There is currently no scientific evidence indicating EMFs from subsea cables of any kind affect marine mammals, but potential interactions and effects are not well studied.
- Key marine mammal prey species of forage fish, squid, and small crustaceans like copepods and krill are not known to be EMF-sensitive, so EMF effects on these organisms will likely be negligible.

Broad Answer

Electromagnetic field (EMF) sources from offshore wind development include underwater electric cables that connect turbines together, connect turbines to at-sea substations, and transmit power generated from offshore wind to shore (see *What are the major components of an offshore wind farm?*). These cables emit low-frequency electromagnetic radiation, as do other common natural and anthropogenic sources like Earth's geomagnetic field, thunderstorms, communications cables, bridges, and power lines. Marine animals use natural EMF sources to sense nearby prey and predators and for long-distance navigation, so anthropogenic EMFs may potentially disrupt these relationships. While marine mammals can theoretically detect EMFs from subsea cables (associated with offshore wind development, communications, and other purposes), interactions have not been documented. Marine mammal prey species like forage fish, squid, and small crustaceans like copepods and krill are not known to be EMF-sensitive, so direct EMF effects on these taxa will likely be negligible. For species that are EMF-sensitive, it is unlikely that EMFs from offshore wind cables will significantly affect most marine species' sensory abilities because EMF strength decays quickly with distance from seafloor cables (within 10s of meters). Mitigating cable designs (shielding, insulation, etc.) and strategic placements (buried or away from key habitats) can additionally reduce potential impacts. Studies to date have failed to identify definitive, substantive risks based on a range of marine species characteristics (EMF sensitivity, habitat preference, feeding behavior, etc.) and seafloor cable EMF features (current type, intensity, temporal variability, etc.). Overall, more research is needed to better understand interactions between marine species and EMFs from offshore wind and quantify potential impacts. However, available evidence indicates exposure effects (if any) at EMF intensities relevant for offshore wind cables are minimal with no serious consequences for organism function, fitness, or population health.

Detailed Answer

Low-frequency electromagnetic radiation is produced by a range of common natural and anthropogenic sources, such as Earth's geomagnetic field, thunderstorms, power lines, electric home appliances, cars, etc. All anthropogenic electromagnetic fields (EMFs) consist of two components: an electric field, which is produced by an electric charge, and a magnetic field, produced when an electrical current flows through a cable (Figure 8; Faraday 1832, Maxwell 1865). These currents can be either direct current (DC) or alternating current (AC). DC only flows in one direction, and DC EMFs are therefore constant over time, while AC alternates direction, causing fluctuating EMFs. In the case of AC, changes in magnetic fields (rotation, movement) will also induce secondary electric fields (Figure 8; Maxwell 1865).

Electromagnetic field (EMF) sources from offshore wind development include subsea electric cables that are buried or laid along the seafloor to connect turbines together, connect turbines with the offshore substation, and to transmit power generated from offshore wind to shore where it can reach electricity consumers (Figure 9; see *What are the major components of an offshore wind farm?*). Floating wind farms also involve electric cables suspended in the water column (Figure 9).

Subsea electric cables (both AC and DC) have been historically prevalent in the marine environment, for decades in many cases, and subsea cables from offshore wind development are part of an extensive, existing infrastructure for power transmission that generates anthropogenic EMFs (Figure 10). It is necessary to consider the effects of EMFs from offshore wind cables because many marine animals and certain life stages for some species may be sensitive to one or both kinds of EMF via their natural senses of electroreception and/or magnetoreception , which allow organisms to detect electric and/or magnetic fields, respectively. Marine animals typically use electroreception for short-range detection (e.g., sensing nearby prey, predators, or conspecifics), whereas MR is usually employed for long-range navigation over large distances (e.g., during migration).

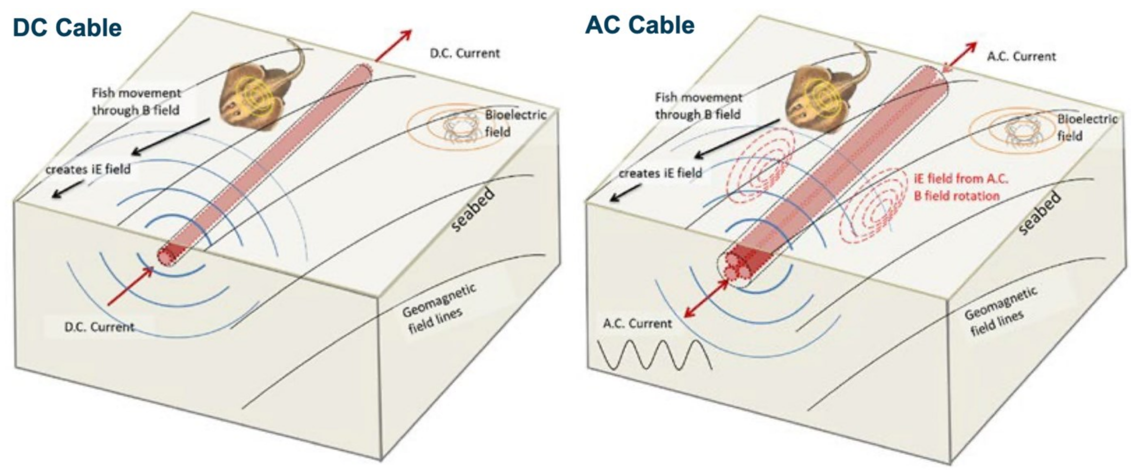

Figure 8. Natural and anthropogenic EMFs around direct current (DC – left) and alternating current (AC – right) buried cables. Natural sources: Earth's geomagnetic field (brown) and organisms' bioelectric fields (orange). Anthropogenic sources: magnetic fields emitted from cables (blue) and induced electrical fields (red) from species movement and magnetic field rotation. Source: SEER EMF and Marine Life Webinar, adapted from Newton et al., 2019).

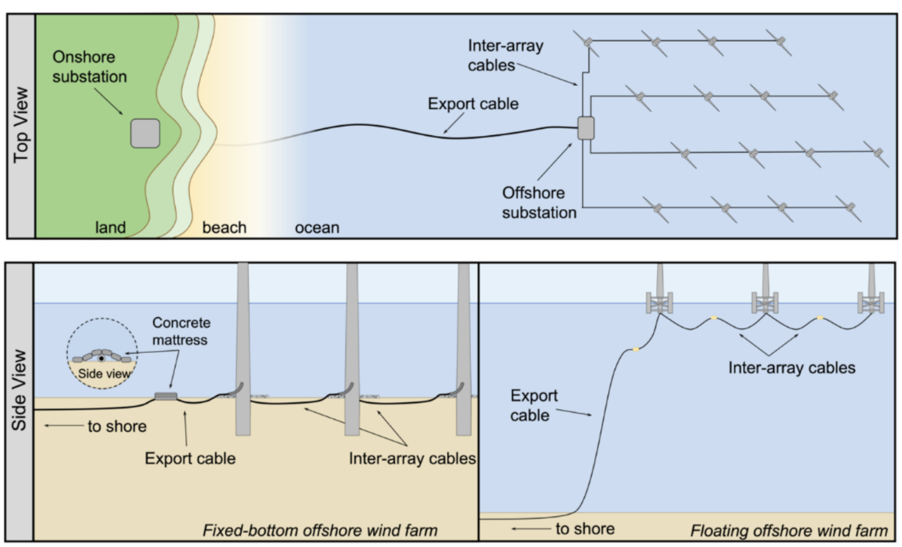

Figure 9. Top: Bird's eye view of electric cable connections around an offshore wind farm. Bottom: How electric cables are used at fixed-bottom (left) and floating offshore wind farms (right). Not to scale. Source: SEER Electromagnetic Field Effects on Marine Life Educational Research Brief (SEER 2022).

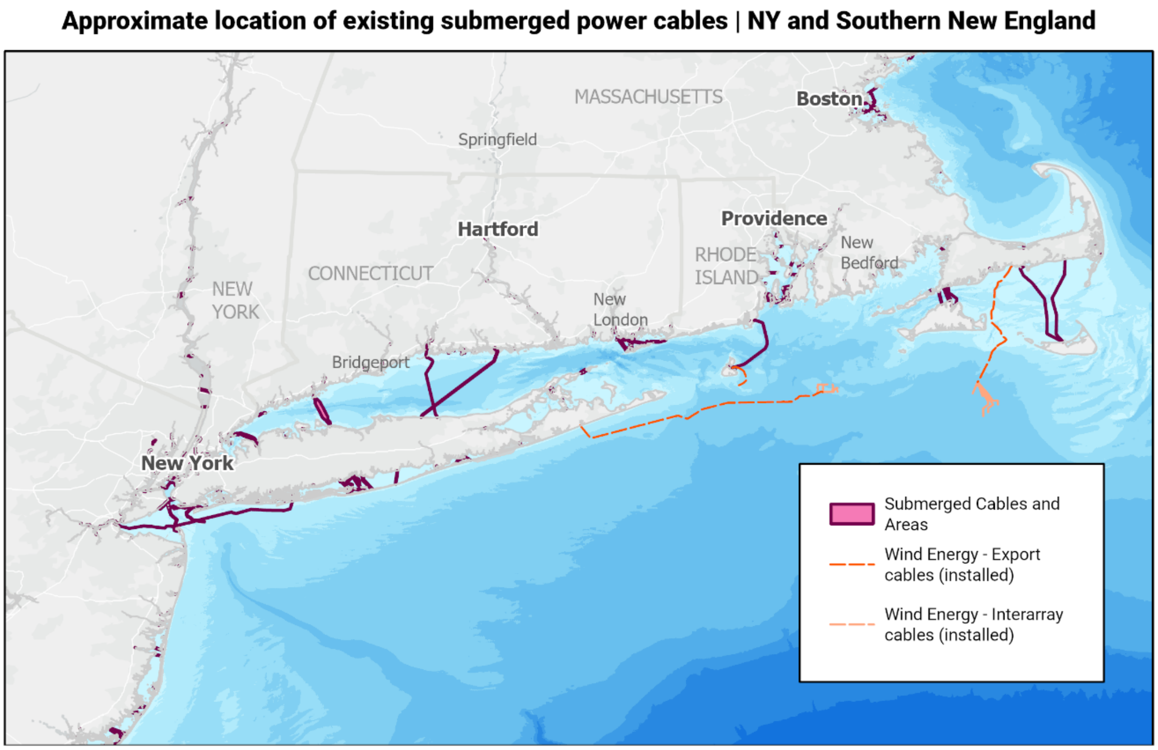

Figure 10. Approximate locations of a subset of existing subsea power cables from offshore wind energy (orange) and other types of power transmission (purple) in New England and the New York Bight based on publicly available spatial data. Note that the status (planned, currently used, no longer operational) of cable data is not available and some data may be restricted due to security concerns. Thus, this map may not be representative of current submerged power cables in the region but aims to show offshore wind transmission cables in the context of other potential sources of EMF. Source: Marta Ribera, The Nature Conservancy

Marine mammals and EMFs

Marine mammals are not known to be electroreceptive. Terrestrial monotremes (platypus, echidnas) and the estuarine Guiana dolphin are the only mammals known to use electroreception (Czech-Damal et al. 2011, England & Robert 2021). Recent studies have demonstrated behavioral and anatomical evidence for electroreception in bottlenose and Atlantic white-sided dolphins, suggesting further research on electroreception in delphinids is warranted (Hüttner et al. 2022, Mynett 2022). Notably, however, Mynett (2022) did not identify electrosensory structures in either harbor porpoises or minke whales, and there is no available scientific evidence to suggest other cetaceans are electroreceptive.

By contrast, marine mammals likely use magnetoreception for long-distance migration. A 2011 report to the Bureau of Ocean Energy Management (BOEM) identified 14 cetacean species occurring in U.S. waters for which evidence of sensitivity to Earth's geomagnetic field exists (Normandeau et al. 2011). In an empirical study, Kremers et al. (2014) demonstrated captive bottlenose dolphins could distinguish between two otherwise identical objects based on their magnetic properties. Several observational studies from around the world have also found significant associations between strandings of various cetaceans (including dolphins, pilot, fin, gray, and sperm whales) and natural geomagnetic patterns and anomalous events (Kirschvink 1990, Walker et al. 1992, Ferrari 2017, Vanselow et al. 2018, Granger et al. 2020). These studies suggest fluctuations in Earth's magnetic field may disrupt magnetoreception-based navigation in cetaceans, making them more likely to strand under certain conditions. Though some biological mechanisms for magnetoreception in cetaceans have been hypothesized, they have yet to be confirmed.

Currently, there is no evidence to suggest anthropogenic EMFs emitted from subsea electric cables of any kind (including around offshore wind farms) affect cetaceans. However, these species can theoretically detect such fields. Potential interactions with offshore wind energy development that have yet to be scientifically investigated include: (1) whether seafloor cables affect cetaceans that forage in or near benthic habitats like dolphins, humpback, gray, and sperm whales (Ware et al. 2014, Irvine et al. 2017, Quigley et al. 2022, Webber et al. 2024), and (2) if cables suspended in the water column (for floating turbines) may affect navigational magnetoreception in nearby cetaceans. However, given how quickly EMF strength decreases with distance from seafloor cables, along with mitigating designs and placements, it is unlikely that EMFs from offshore wind electric cables will significantly impact cetaceans' biosensory abilities. For example, modeled EMFs for ten existing or proposed offshore wind seafloor cables indicate magnetic field strength declines to background or negligible levels within 10 meters of a cable, and strategic placements to bury cables and place them away from known critical habitats can help reduce potential EMF exposure (Normandeau et al. 2011). Protective cable design components such as insulation, shielding, and armor additionally mitigate EMF emissions from subsea cables by creating a physical barrier to electric fields. Less is known about in situ EMFs associated with dynamic cables suspended in the water column for floating offshore wind farms, and scientific research is still in early stages.[81] Overall, Normandeau et al. (2011) highlighted a lack of specific information concerning subsea cable EMF effects on marine mammals, but noted potential responses from exposure "may include a temporary change in swim direction or a deviation from a migratory route […], but these theoretical responses have not been tested." While research is lacking on magneto-sensitivity in cetaceans, EMFs from offshore wind cables are not expected to significantly alter whale migration behavior due to these species' high mobility and likely limited spatiotemporal exposure to offshore wind cable EMFs (BOEM 2024b).

Other marine species

While electroreception capabilities are rare in marine mammals, many fish species have specialized electroreceptors (ampullary organs) that allow them to detect nearby electric fields (Figure 11; reviewed in Newton et al. 2019, England & Robert 2021). Additionally, long-distance migration and homing behaviors suggest some marine fishes, turtles, and invertebrates use magnetoreception for navigation and orientation (reviewed in Formicki et al. 2021; Naisbett-Jones & Lohmann 2022; Nyqvist et al. 2020). Like cetaceans, exact biological structures and mechanisms for magnetoreception have not been confirmed in other species, and this is an active area of research. Research on EMF interactions with these taxa can be subset into studies on the effects of natural EMFs like geomagnetic and bioelectric fields, and studies on the effects of anthropogenic EMFs like those emitted from subsea cables and other human-made structures. Studies of marine species' responses to natural EMFs have generated basic insights about which species, life stages, and behaviors are EMF-sensitive, as well as about biologically relevant EMF characteristics (range, intensity, etc.; see above reviews, as well as Fischer & Slater 2010; Normandeau et al. 2011).

EMF effects on marine mammal prey could potentially impact marine mammal behavior and energetics. However, key prey species groups like forage fish, squid, and small crustaceans like copepods and krill are not known to be EMF-sensitive (Williamson 1995, Hanlon & Shashar 2003, Collin & Whitehead 2004, Derby & Thiel 2014, Naisbett-Jones & Lohmann 2022). Therefore, concerns about EMF effects on marine mammal prey and any potential indirect impacts on marine mammals are minor.

[81] FLOWERS: Floating offshore wind Environmental Response to Stressors (video)

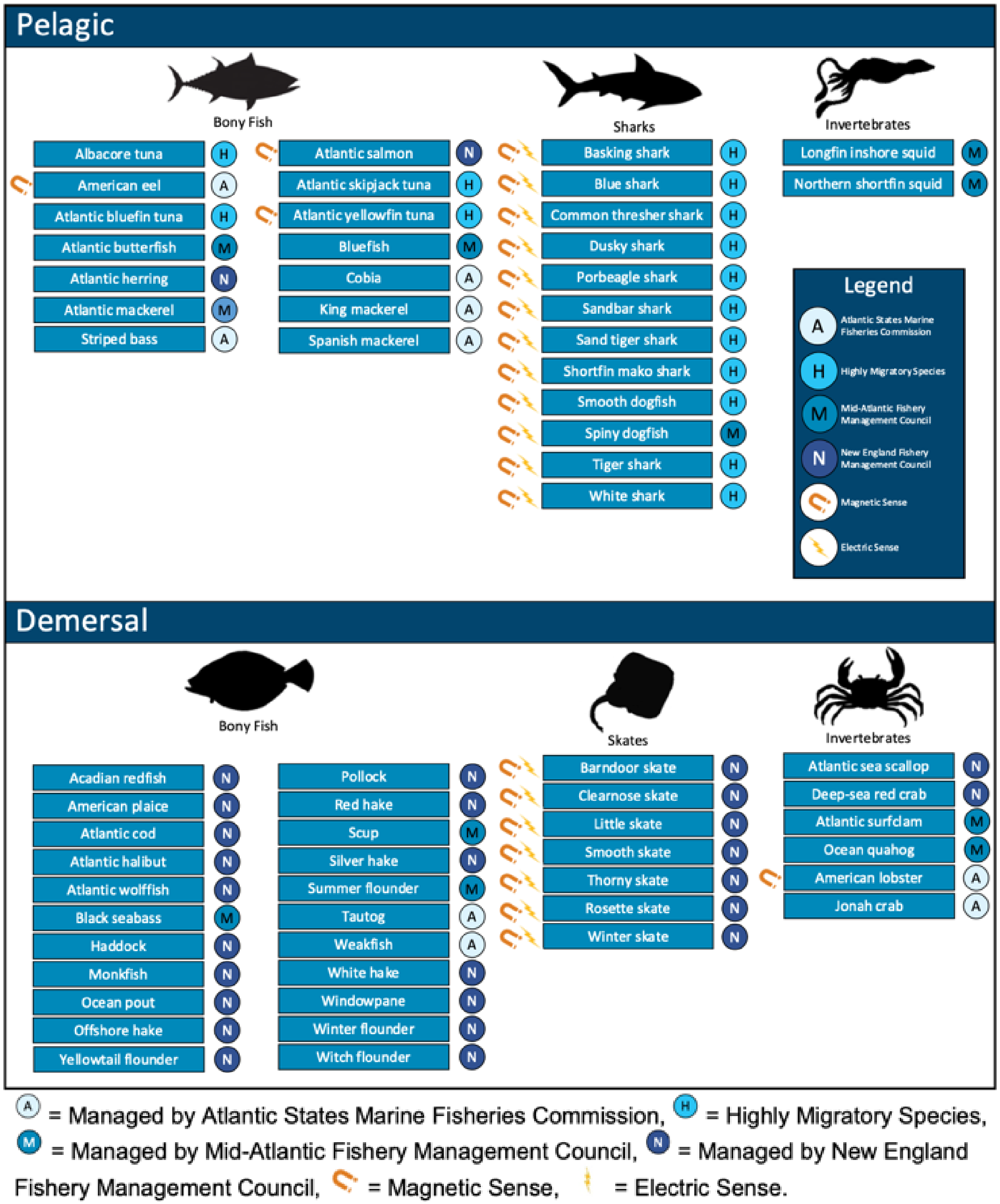

Figure 11. Magneto- and electrosensitivity of marine fisheries species in southern New England (USA). Source: (CSA Ocean Sciences Inc. & Exponent Inc. 2019).

Broadly speaking, there have been recent calls for more empirical work on marine species and EMF interactions given expected increases in anthropogenic EMF sources in marine environments (Hutchison et al. 2020b, Klimley et al. 2021). Current understanding of anthropogenic EMF effects on marine species is based primarily on field and lab studies of behavioral and physiological responses and early life stage development for a few species, including elasmobranchs, sturgeon, eels, crabs and lobsters, and commercially important fishes (as reviewed in Taormina et al. 2018, Hutchison et al. 2020b, Albert et al. 2020, Formicki et al. 2021). So far, this body of work draws primarily from non-offshore wind EMF sources, such as subsea electric cables from oil and gas platforms and regional power transmission cables like the

Cross Sound (NY/CT), Neptune (NY/NJ), Sea2shore (NY/NJ), and Trans Bay (CA) cables. Field studies conducted at these sites and others indicate anthropogenic EMF effects on fish and invertebrates are temporary, highly localized, and non-lethal (Table 2-3), though all authors advocate for additional research to better quantify in situ features of EMFs and species responses. In a targeted assessment of potential impacts to fisheries species in southern New England from offshore wind subsea cable EMFs, BOEM determined impacts would be negligible for several pelagic and demersal species due to weak EMF strength and rapid decay with distance from source, lack of species sensitivity to EMFs, and species habitat preferences (CSA Ocean Sciences Inc. & Exponent Inc. 2019). In 2021, the New Jersey Department of Environmental Protection determined that "research to date has not shown significant evidence that EMF from undersea electric cables causes physiological impacts to individual species and populations or impacts to habitat" (Bilinski 2021). Collectively, studies and reports tend to highlight potential risks for EMF-sensitive benthic, demersal, and migratory marine species, but "few, if any have demonstrated negative impacts of biological significance" like consequences for organism function, fitness, and population health (Bilinski 2021).

As part of offshore wind permitting in the U.S., developers conduct computational modelling of EMFs from power cables at the individual project scale. In one example, Revolution Wind Farm found calculated EMF levels above buried cables were below reported experimental thresholds for behavioral effects in magneto-sensitive species and for detection in local electro-sensitive species (Exponent Inc. 2023). In the water column, EMFs levels were calculated to be well below those associated with documented chronic effects on fish (Exponent Inc. 2023). However, additional post-construction monitoring data will be needed to validate these predictions.

Table 2. Field studies on behavioral effects of anthropogenic EMFs from subsea cables on marine invertebrate species.

Species	EMF source	Observed effect	Study location	Reference
Yellow rock crab, red rock crab	Subsea AC cables associated with offshore oil and gas	No effect on movement/behavior	Santa Barbara Channel, CA, USA	(Love et al. 2015)
Dungeness crab, red rock crab	Subsea power cables	No barrier to movement	Puget Sound, WA, and Santa Barbara Channel, CA, USA	(Love et al. 2017a)
American lobster	Subsea DC cable under rearing cage	No barrier to movement, increased exploratory activity	Long Island Sound, NY, USA	(Hutchison et al. 2018, 2020a)
Red rock crab	Subsea AC cables associated with offshore oil and gas	No barrier to movement, no effect on behavior	Santa Barbara Channel, CA, USA	(Williams et al. 2023)
Benthic invertebrate community	Subsea AC cable associated with offshore oil and gas	No differences in community structure between energized and unenergized cables, unburied pipeline, and reference area; no cable attraction or avoidance	Santa Barbara Channel, CA, USA	(Love et al. 2016, 2017b)
	Subsea AC cable at tidal energy test site	No differences in community structure between cable and reference area	France	(Taormina et al. 2020)

Research on subsea cable EMF characteristics and marine species responses continues to grow, and we can gain useful insights from similar industries like marine renewable energy (MRE), which uses underwater turbines to harvest wave, tidal, and current energy. Peer-reviewed findings are synthesized and reported every four years in a dedicated EMF section of the State of the Science Report on global MRE effects,[82] the latest of which concluded that "there is consensus among the scientific community that EMFs from small-scale MRE developments (one to six devices) are not harmful and do not pose a risk to marine animals" but recommended developing industry standards for subsea cable deployment and in situ EMF monitoring to understand cumulative EMFs from larger MRE projects (Garavelli et al. 2024). In a comprehensive 2024 report specific to offshore wind in the U.S. that considered available research on EMFs and marine fauna (mammals, fish, invertebrates, plants, turtles, birds, bats, and insects), BOEM concluded that "EMF emissions from [offshore wind energy development] could elicit a response from electro- and magneto-sensitive species...[but] any effects are anticipated to be species-specific, limited to individuals in the immediate vicinity, and biologically non-significant" (BOEM 2024b).

Table 3. Field studies on behavioral effects of anthropogenic EMFs from subsea cables on marine fish species.

Species	EMF source	Observed effect	Study location	Reference
Thornback ray, small-spotted catshark	Experimental in-situ subsea power cable	No barrier to movement, limited effects on feeding and swimming behavior	Scotland	(Gill et al. 2009)
Little skate	Subsea DC power transmission cable	No barrier to movement, increased exploratory and/or foraging behavior	Long Island Sound, NY, USA	(Hutchison et al. 2018, 2020a)
Chinook salmon, green sturgeon	Subsea DC power transmission cable	No barrier to movement or migration	San Francisco Bay, CA, USA	(Klimley et al. 2017, Wyman et al. 2018, 2023)
American eel	Subsea DC power transmission cable	No barrier to movement, faster movement for some individuals	New Haven Harbor, CT, USA	(Hutchison et al. 2021)
European eel	Subsea AC power transmission cable	No barrier to migration, limited effects on swimming behavior	Baltic Sea, Sweden	(Westerberg & Lagenfelt 2008)
Fish community	Subsea power cables and junction boxes at naval facility	No difference in species richness between energized and unenergized cable states; no cable attraction or avoidance	Fort Lauderdale, FL, USA	(Dhanak et al. 2016)
	Subsea AC power transmission cables	No difference in fish abundance between cable and control transects; no evidence of cable attraction or avoidance	British Columbia, Canada	(Dunham et al. 2015)
	Subsea AC cable associated with offshore oil and gas	No differences in community structure among energized cable, unburied pipeline, and reference area; no evidence of cable attraction or avoidance	Santa Barbara Channel, CA, USA	(Love et al. 2016, 2017b)

[82] About the Technology Collaboration Programme on Ocean Energy Systems-Environmental: https://tethys.pnnl.gov/about-oes-environmental

For More Information

- SEER Educational Research Brief on EMF: https://tethys.pnnl.gov/sites/default/files/summaries/SEER-Educational-Research-Brief-Electromagnetic-Field-Effects-on-Marine-Life.pdf
- Offshore Wind Facts EMFs and Offshore Wind: https://offshorewindfacts.org/wp-content/uploads/2024/04/Deeper-Dive_-EMFs_FINAL-1.pdf
- BOEM Research Brief EMF from Offshore Wind Facilities: https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/BOEM-Electromagnetic-Fields-Offshore-Wind-Facilities_2.pdf
- France Energies Marines Effects of EMF from Offshore Wind Cables on Marine Organisms: https://tethys.pnnl.gov/sites/default/files/publications/COME3T-bulletin-7-CEM-EN-BD.pdf

Marine Mammal Research and Monitoring

How do scientists study whales?

- Methods for studying large whales fall into the following general categories: visual observations via boat or aircraft; underwater acoustics to record whale calls and other vocalizations and clicks; physiological and biological sampling to understand more about whales' health, such as stress levels, reproductive status, and diet; biologging or tagging animals to gather information about their movements and behavior; and resighting of individual animals (e.g., cataloging) to monitor individuals over long periods of time.
- Permits are required to ensure that scientific research on whales is conducted by highly experienced scientists and is as safe as possible.
- Research scientists and natural resource managers carefully consider which methodologies may be able to answer their specific research question with the least possible impact to the animals.

Detailed answer

The development of sampling techniques and technologies over time has led to a wide breadth of tools and methods to better understand the health, population status, distribution, and behavior of large whales globally as well as interactions between whales and other components of marine ecosystems. Some of the technologies developed have also been implemented for monitoring and risk mitigation for large whales in the context of offshore wind development. Ultimately, because large whales only spend a portion of their life at the ocean's surface, are highly mobile, and not suited for captive research procedures, it can be difficult or impossible to answer some key questions about whales. However, the suite of tools available to collect data on large whales can be used to answer many scientific questions. Advancements in technology (e.g., tagging) and new methods (e.g., drones, environmental DNA) continue to be developed.

It is important to consider the research question at hand when assessing methodologies, and to choose the most applicable research method to best answer the question, without causing undue harm and/or suffering to the animals studied. A key consideration is whether the method is considered invasive (i.e., causes tissue injury) or non-invasive (i.e., does not cause tissue injury; Andrews et al. 2019). For large whales, research methods generally fall into the following categories (Table 4):

- Visual observations. These typically occur from boats or aircraft and can be either opportunistic sightings or systematic surveys. Additional visual observations can come from mitigation monitoring for marine mammals around industry activities (see *What are protected species*

observers and what data do they collect?). Imagery can also be obtained from technology rather than human observation; digital aerial surveys and satellites are used to conduct some types of whale monitoring remotely.
- Acoustic recordings. Passive acoustic monitoring (PAM) data are collected via hydrophones either fixed in one place for a period of time or towed by boat or platforms such as autonomous underwater vehicles to collect data across an area (but for a shorter period or time; reviewed in van Parijs et al. 2021).
- Biologging (e.g., tagging). Transmitters or other biologging devices are deployed on animals to gather information about their movements and behavior (see *What are the risks and benefits of tagging whales?).* There are both invasive and non-invasive tag types.
- Biological sampling. This includes invasive approaches like taking tissue samples (via skin or blubber biopsy) from live or dead whales (via necropsy; see *How are necropsies conducted?* and *What can we learn from stranding data?*). Some types of biological samples can also be collected non-invasively, such as sampling feces, blow, and other biological material after it has been shed into the environment.
- Photo Identification. Resighting individually identifiable animals over time is used to gather information about their habitat use, longevity, and other life history data. This is often done based on unique markings.

Research scientists and natural resource managers must carefully consider which methodologies are best suited to answer their specific research question with the least possible impact to the animals. Studying whales also requires specific permits from NOAA Fisheries. To obtain these permits, researchers must demonstrate in their applications that the proposed project is bona fide and humane (e.g., safe), and that they have sufficient experience with the proposed specific research methodologies, species, and even regions in which work is proposed. The term “bona fide research” means scientific research on marine mammals, the results of which a) likely would be accepted for publication in a scientific journal, b) are likely to contribute to the basic knowledge or marine mammal biology or ecology, or c) are likely to identify, evaluate, or resolve conservation problems (16 U.S.C. § 1361).

For More Information

- NOAA Fisheries: Whale and Dolphin Research in the Northeast
- NOAA Fisheries: Passive Acoustic Technologies
- New England Aquarium (NEAq): Virtual Aerial Survey (video)
- NEAq Blue Planet Science: Aerial Survey Data (video)
- NEAq: Know Your Tag Types and Whale Photo Identification
- NOAA Fisheries: Marine Mammal Photo Identification
- NOAA Fisheries: Tagging Whale with Drones
- Woods Hole Oceanographic Institution: Whale Biopsy Collection (video)
- Ocean Wise Learn & Explore Blog: How researchers learn about whales via environmental DNA

Table 4. Key methods used to study whales, including potential end products, benefits and limitations, and examples in the literature.

Method	Description	Possible end-products	Benefits	Limitations
Visual Observations: Boat- or plane-based systematic human observation (examples: Barlow et al. 1995, 2001, Roberts et al. 2016)	Observation of marine mammals from dedicated observers using the naked eye and/or binoculars. Standardization of methods includes (1) constant scanning of the sea surface by observers, (2) immediate recording sighting, including the species and number of animals, behavior, distance and angle from the ship and aircraft, and (3) record effort and metadata on height of the vessel or altitude of the plane off the water, and other characteristics.	▪ Estimates of density, occupancy, occurrence, habitat use, or distribution at variable spatiotemporal scales; presence of particular individuals.	▪ Reliance on trained observers. ▪ Can report time-sensitive sitings to inform mitigation (e.g., sightings of North Atlantic right whales to trigger speed restrictions), or stranding response (e.g., if the individual's health is compromised) ▪ Provides data that can be analyzed using reliable statistical frameworks. ▪ Non-invasive method.	▪ Because physical presence of personnel is required, human safety must be considered. ▪ Difficult to obtain data on species that are cryptic, rare, clumped, or that surface infrequently (e.g., deep-diving whales). ▪ Daylight, weather vessel/plane availability, and cost may limit survey time.
Visual Observations: Incidental sightings (examples: Firestone et al. 2008, Fiedler et al. 2018, Brown et al. 2022)	Opportunistic sightings including from passenger vessels and whale watching vessels. This may also include data collected by Protected Species Observers for mitigation purposes.	▪ Timing and duration of habitat use (with repeated sampling), species and individual presence, residence (i.e., how long animals spend in a specified area), site fidelity (whether animals return to the same location between years).	▪ Provides data that can be used to evaluate statistical models and to improve our understanding of species presence. ▪ Community science can serve as an important teaching and science communication tool. ▪ Can provide information on species that are difficult to detect or rarely encountered on standardized surveys. ▪ Non-invasive method.	▪ Non-standard survey design. ▪ Observers typically do not prioritize looking for whales for the duration of a trip, possibility of missed or undetected whales that confound the dataset. ▪ Opportunistic data can be difficult to incorporate in a statistically appropriate manner, particularly as the trackline of the vessel and time spent searching for whales (e.g., survey effort) may not be reported. ▪ As above, safety, weather, and vessel limitations dictate the efficacy of data collection.
Visual Observations: Remote sensing (examples: Bröker et al. 2019, Cubaynes et al.	Imagery of the sea surface for the detection of whales using high-resolution satellites or digital aerial surveys, where a camera is attached to the bottom of an aircraft and images or video is	▪ Individual information: presence, health (e.g., entanglements, deceased animals) ▪ Population-level information: species	▪ Does not rely on trained observer presence in the field. ▪ Digital aerial surveys can fly higher and faster than visual aerial surveys, so	▪ Data are not analyzed in real time so detections of cryptic, rare, injured, or dead marine mammals may not occur in a timely manner to facilitate mitigation or stranding response.

Method	Description	Possible end-products	Benefits	Limitations
2019, Robinson Willmott et al. 2021)	captured while the plane flies along pre-determined survey transects. Satellite-derived sighting methods are largely in development, though further research is being conducted to improve and tailor the detection frameworks for species.	density and distribution, seasonal variation, habitat use.	more efficient and fewer safety concerns. ▪ Digital aerial surveys provide data that can be incorporated into statistical models, after biases are corrected. ▪ Both methods include permanent records of animal detections for species identification and verification can occur after the survey. ▪ Non-invasive method.	▪ Safety, weather, and aircraft limitations dictate the efficacy of data collection for digital aerial surveys. ▪ Detection biases in data are difficult to correct and have not been explored for digital aerial surveys. ▪ Satellites may lack spatial resolution needed to detect and ID whales, and only sample portions of the sea surface in a given day. Cloud cover and darkness impede detectability. ▪ Digital aerial surveys typically do not detect many large whales and are designed for ecosystem-level sightings information (e.g., birds, turtles, sharks, fish, marine mammals).
Acoustic recordings (examples: Parks et al. 2011, Castellote et al. 2012, Davis et al. 2020, Baumgartner et al. 2020)	Data on the sounds produced by whales, such as calls, songs, and moans. Typically referred to as passive acoustic monitoring (PAM). Fixed acoustic recorders can either be mounted to the ocean floor or attached to surface buoys for long-term data collection on vocalizations. Recorders can also be towed behind a vessel, where vocalizations can be matched with other data collection (e.g., visual observation) or mounted on uncrewed underwater gliders that travel along a pre-determined track	▪ Individual-level information: In some cases, specific coordinates of vocalizing animal, behavior ▪ Species-level information: Timing of presence of vocalizing species, species composition, behavior type. In some cases, it is possible to infer population or sub-population-level groups based on unique vocalization features.	▪ Data collection requires little on-site human involvement. ▪ Data can be collected as archival (e.g., recorded for a period of time and analyzed after) or in near-real time (e.g., data are analyzed as they are received). ▪ Software exists to auto-detect and identify some species in recordings. ▪ Continuous, long-term, non-invasive data collection.	▪ Individuals need to be vocalizing to be detected. Whale vocalization patterns vary by species, age/sex, behavior, and other characteristics, so acoustic monitoring is more effective at detecting some animals than others. ▪ Though data for some species can be auto-analyzed, manual checking is still required. ▪ Limited ability to determine whether repeated vocalizations are from one animal or many, so abundance is difficult to extract from these data.

Method	Description	Possible end-products	Benefits	Limitations
	at multiple depths to obtain oceanographic data.		▪ Scalable based on the study area size.	▪ Limited detection range for many species and call types. ▪ Some species produce very similar vocalizations, so it is challenging to confidently distinguish them in recordings.
Biologging (e.g., tagging; examples: (Parks et al. 2012, Friedlaender et al. 2016, Andrews et al. 2019))	Tags, in this context, are biologging devices that are attached externally to an individual. Some tags need to be retrieved while others can remotely transmit data via satellite or other means. Tags can carry a range of sensors, including satellite transceivers, pressure sensors, oceanographic recorders (e.g., to obtain information on temperature and salinity), and even hydrophones and cameras. Non-invasive tags include attachment via harnesses, peduncle belts, and suction cups. Invasive tags include attachment via anchors, bolts, and consolidated implantable tags. Permits and substantial training are required to conduct this activity, and ethical considerations are made to minimize risk to live tagged animals (for more on ethical discussions around cetacean research, see *What are the risks and benefits of tagging whales?*)	Data can be obtained on the location, dive behavior, oceanographic conditions, vocalizations (via microphones) and potentially prey and group interactions (via cameras). Data can be used to understand the movement, habitat use, and behavior of individuals.	▪ Can provide fine-scale information on individual movement and behavior when individuals are underwater (non-observable). ▪ Able to collect data in poor conditions and at night. ▪ Provides data on individuals over time (rather than snapshot observations).	▪ Some tag types are invasive (i.e., involve puncturing live animal tissue). ▪ Potential for behavioral disturbance. ▪ Data from individuals may not be representative of the whole population. ▪ Many logistics involved in tag deployment and retrieval. ▪ Potential health risks to animals if done improperly (e.g., poorly placed tags can penetrate beyond blubber into underlying tissue).

Method	Description	Possible end-products	Benefits	Limitations
Biological sampling: necropsy (examples: Geraci & St Aubin 1979, Alzugaray et al. 2020, Raverty et al. 2024, Thorne & Wiley 2024)	A necropsy is the examination of a deceased animal to identify cause of death and collect other information on the health of the individual, the species, and the marine environment. A necropsy includes measurements, observations, and taking samples, including tissue.	When possible, data are obtained on the sex, age, condition, and/or overall health of an individual. This may include understanding of cause of death, potential human interaction (e.g., entanglement, vessel strike), disease, and contaminants.	▪ Does not involve sampling of live individuals. ▪ Can provide information on species that are rare or difficult to otherwise study. ▪ Can provide information on causes of stranding events.	▪ Thoroughness is dependent on state of decomposition. ▪ May be difficult to determine cause of death. ▪ Not all carcasses/dead stranded individuals are able to be necropsied.
Biological sampling: biopsy (examples: Gauthier & Sears 1999, Noren & Mocklin 2012, Hunt et al. 2013)	A biopsy involves obtaining a small sample of skin and blubber from a carcass or live individual, typically using a small dart shot from a crossbow.	▪ Individual-level information: individual health, sex, fat content, genetics/genomics, hormones, disease, microbiome, contaminants, diet. ▪ Population-level information: sex ratio, health, genetics/genomics, stress levels	▪ Provide key information on healthy, live animals that would otherwise not be obtained. ▪ Biological data on healthy animals provides a baseline for comparison when ill animals are assessed. ▪ Though invasive, biopsies do not cause serious injury.	▪ Like other methods described here, field logistics can be complex – dependent on suitable weather conditions, locating free-swimming animals and achieving sufficient proximity for successful deployment, etc. ▪ Invasive method.
Biological sampling: eDNA, excretions (examples: (Hunt et al. 2013, Baker et al. 2018, Alter et al. 2022, Suarez-Bregua et al. 2022))	Excretions include feces and blow samples (i.e., exhalations of whales that contain particulate matter and DNA, similar to a human sneeze). eDNA (environmental DNA) is genetic material collected in seawater samples, sometimes from whale fluke prints.	▪ Individual-level information: sex, genetics/genomics, hormones, disease, microbiome ▪ Population-level information: sex ratios, population health ▪ Species presence and occurrence	▪ Non-invasive method. ▪ Can provide information on health, stress, and condition of individuals to inform population status and impacts from anthropogenic stressors. ▪ For eDNA, prey or ecosystem community data can also be obtained.	▪ Immediate excretion collection can be difficult in the field – sampling exhalations essentially requires holding a petri dish above a whale as it surfaces (using a drone or long pole). ▪ Difficult to verify or ground-truth, especially for eDNA.
Biological sampling: drone imagery	Drone imagery is typically used to collect data on whale health, using a proxy of their overall body	▪ Individual-level information: body condition, length, scarring,	▪ Non-invasive method.	▪ Federal rules for drone operation can be limiting and are modified on a regular basis.

Method	Description	Possible end-products	Benefits	Limitations
(examples: Hunt et al. 2013, Smith et al. 2016, Aniceto et al. 2018, Christiansen et al. 2018)	condition (fatness relative to overall length, similar to a human Body Mass Index). Drones can also be used to study skin condition, scarring, behaviors, and morphometric/physiological changes.	visual health assessment (e.g., skin coloration, lesions, disease) ▪ Population-level information: body condition average and variability, length distribution, scarring rates, population health.	▪ Can provide a general measurement of relative animal health ▪ Can capture footage through top layer of sea surface. For species that do not surface with a lot of their body (e.g., fin and sei whales), drone data provide a visual assessment that cannot be obtained from boat-based observations. ▪ In tandem with other methods, drones can provide a powerful link between visual and physiological health cues.	▪ Body condition generally reflects energetic storage, but details on the physiology (e.g., blubber fat content, blubber vs. muscle) cannot be determined. ▪ There are many post-processing steps, to convert to real-world (e.g., meters, feet) measurements. ▪ Bias or uncertainty in all steps of data collection not well understood.
Photo-identification (examples: (Katona & Whitehead 1981, Katona & Beard 1990, Hunt et al. 2013, Olson et al. 2016))	Involves taking photos of distinctive markings on whales and comparing them to a catalog of known individual whales with possible repeated observations cataloged over time. For some large whale species, individuals can be identified by unique external characteristics. For example, fin whales have unique fin shapes and scars, humpback whales have unique patterns on the underside of their flukes (tails), and North Atlantic right whales have unique patterns of hardened skin on their heads.	▪ Individual-level information: residency, site fidelity (i.e. returning to the same location in multiple years), calving rate, sex (if seen with calf), health (e.g., change in external lesions or coloration over time) ▪ Population-level information: population site fidelity and habitat use, population dynamics (e.g., birth and death rates, population size), population health (e.g., scarring rates)	▪ Non-invasive method. ▪ Can easily be added to other data collection efforts (e.g., visual surveys). ▪ Can be conducted by both scientists and members of the public. ▪ There are accessible online repositories to submit images for cataloging purposes.	▪ Substantial cataloging efforts are needed before population-level inferences can be made. ▪ Some training is required to obtain suitable images for cataloging, especially for species with less identifiable markings (e.g., fin whales). ▪ Effectiveness dependent on image quality. ▪ AI or auto-classifiers have been difficult to develop for cataloging/matching purposes. ▪ Substantial time effort to conduct matching, especially for large catalogs.

What are the risks and benefits of tagging whales?

- Studying the habitat and movement of whales can be difficult as they spend considerable amounts of time below the surface, out of sight. Satellite tags can help researchers understand where whales go when they are not visible (e.g., when they are underwater, inhabiting understudied or novel habitats, at night, in bad weather, etc.). However, researchers must also consider the potential for negative impacts of tagging.
- Research on whales using tags requires permits under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). Decisions regarding whether to deploy a tag on an individual, the type of tag attachment, and other logistical decisions depend on a number of factors, including the animal's health and age class, the size of its population (e.g., the importance of the individual to maintaining the population), other existing risk factors like vessel strike and entanglement, species-specific impacts, and gaps in available scientific data for the species. Ultimately, the decision to deploy tags depends on the relative benefit of obtaining tag data compared to other data collection means, specifically regarding whether the scientific questions can be answered with less invasive methods.
- Tags are generally divided into two categories, non-invasive tags that are for short-term studies that generally use suction cups or other exterior attachment methods and invasive tags that are anchored to the skin or implanted for longer-term deployments. Care is taken to ensure that tag designs and choices should not risk the health, welfare, and reproductive status of the tagged animal.
- The scientific community is having ongoing conversations regarding the efficacy of tagging, as well as best practices and technological advancements in tagging methods. Recent discussions have focused on the efficacy and merit of tagging critically endangered North Atlantic right whales, which have been difficult to tag previously due to tag attachment limitations. While there are scientific and management questions about North Atlantic right whales that could most effectively be addressed with tagging data, there is concern that tag deployments could further impact this species. Other less invasive methods (e.g., photo identification, passive acoustic monitoring, statistical modeling efforts) may be useful in broadly understanding migratory patterns and distributions.

Detailed Answer

Studying the habitat and movement of marine mammals can be difficult, as marine mammals spend much of their lives underwater. Deploying tags on whales provides a research opportunity to gather data on whale movement and behavior when they are not visible to observers, and to collect data for longer periods of time rather than snapshots of behavior and locations of whales at the water's surface. "Tags," in this context, are biologging devices that are attached to an individual to gather data on the animal's location, behavior, and/or the environmental conditions around the animal, and can often (depending on the technology) remotely transmit the data via satellites or other means. In most cases, they provide information on the location of individuals (latitude and longitude) over time, but may also provide other types of information, like dive duration and depth and fine-scale 3D movements.

Examples of whale tagging efforts:

- False Killer Whales in Hawaii (Crittercam)
- North Atlantic right whales in the Atlantic (suction cup tag)
- Whale movements in Antarctica (dTag)
- Beaked whale diving behavior (satellite tag)

Tag technologies have been used to understand the movement and behavior of whales and other marine mammals at depth, such as where and how whales feed (Friedlaender et al. 2016, Blair et al. 2016), and how their underwater behavior may influence risk of anthropogenic impacts, such as vessel strikes (Parks et al. 2012). Tag data have also provided information on residency and movements of whales into novel habitats, for example, informing our recent understanding that some humpback whales overwinter in the mid-Atlantic of the United States, where shipping traffic is dense and naval activities are frequent (Aschettino et al. 2020). In addition, tag data have provided information on whale behaviors when observers are not able to effectively monitor them, such as at night or in poor weather, which can help scientists to understand how whales use their habitat in varying conditions (Keen et al. 2019). Ultimately, the information gathered from deploying tags on whales has greatly improved our understanding of whale behavior and distribution during times when, and in places where, observers are not present.

Tag technology has improved over time to reduce tag size, increase tag longevity and attachment duration, reduce the potential for tag breakage, and reduce potential health impacts to tagged individuals. Tags can carry a range of sensors, including satellite transmitters, pressure sensors, oceanographic recorders (e.g., to obtain information on temperature and salinity), and even hydrophones (underwater microphone) and cameras. In addition, there are multiple options for tag attachment depending on the target species and the research goals (Andrews et al. 2019).

Tags are divided into two primary categories: non-invasive and invasive tags, as described in Andrews et al. (2019). Non-invasive tags include attachment via suction cups. Suction cup tags (Figure 12) are used most frequently and have been deployed on many species with little impact. However, they remain attached to the animal for only a few hours to days (Andrews et al. 2019). Although these tags are defined as "non-invasive", they could still alter the behavior of an individual, such as a change in drag and swim efficiency, and possibly chafing (Andrews et al. 2019). Tags considered to be "invasive" are divided into three sub-categories, as defined by Andrews et al. (2019):

- Anchored tags – These tags have external electronics and puncture the skin and enter the tissue. They are typically deployed as a projectile from a crossbow, low-powered pneumatic rifle, or pole. These tags typically do not require handling and restraint of an animal and are therefore used for large whales that cannot be handled due to their size.
- Bolt-On tags – These tags have external electronics and include bolts that pierce tissue, similar to a human earring. Typically, these are deployed on dorsal fins. The deployment of these tags typically requires capture and restraint, and thus generally are not used on large whales.
- Consolidated tags – The electronics for these tags are often combined with a single anchor that is partially implanted in an animal's body. The skin and underlying tissues are punctured and sometimes a portion of the tag extends outward from the body. These tags are deployed remotely (typically using a pneumatic rifle, crossbow, or pole) and do not require animal restraint, so they are suitable for large whale tagging efforts.
- Importantly, care is taken to ensure that tag designs and choices should not risk the health, welfare, and reproductive status of the tagged animal (Andrews et al. 2019). Studies are conducted to assess any health repercussions from tagging efforts, and recent publications have found minimal to moderate temporary impacts, with no long-lasting threats to individual health and longevity (Gulland et al. 2024). In addition, all researchers conducting tagging studies require federal research permits[83] that authorize their activities (see *What is take?* and the FAQ glossary for further discussion of what defines marine mammal harassment). Similarly, when tag data are

[83] More information on federal research permits and authorizations: https://fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-research-and-other-activities

collected, it is best practice to use those data for as many applications as possible. For example, tag data originally obtained by the U.S. Navy to understand baseline behavior of beaked whales[84] have been subsequently used for studies on fisheries bycatch risk (Stepanuk et al. 2018), habitat use and migratory behavior (Thorne et al. 2017), diving behavior (Quick et al. 2017), and foraging behavior (Shearer et al. 2022).

Figure 12. Suction cup tag used for whales. The tag is attached to a long pole in readiness to be deployed on the back of a whale. Unmanned aircraft systems (i.e., drones) are also used to drop suction tags from a position above surfacing whales (not pictured). Credit: New England Aquarium.

In addition, over a series of international workshops, scientists have developed a set of best practices for tagging whales, dolphins, and porpoises (Andrews et al. 2019) to help ensure that potential impacts from tagging are minimized. Best practices are intended for use by researchers, trainees, ethics committees, veterinarians, and regulatory agencies to inform decision making for tag design, deployment, and follow-up health assessments to ensure the health and welfare of tagged marine mammals. In short, Andrews et al. (2019) recommended prioritizing ethical tagging that is scientifically justified, in situations where no alternative data collection method would be more suitable than tagging. Those recommendations include:

- Prior to any data collection, a decision-making framework needs to be implemented that considers potential health impacts to any individual relative to the overall research merit and benefit of the research to the broader population (e.g., McMahon et al. 2012). The decision whether to tag is detailed in a figure from Andrews et al. (2019; Figure 13).
- Once tagging is identified as the most suitable data collection method for the research or management question, other methodological parameters should be considered, including the sample size of tagged individuals, tag type, attachment duration and battery life, duty cycle (i.e., how frequently the tag records data), and the types of sensors needed to address the research or management questions.
- Because animals may be affected by many steps of the tagging process (e.g., close approaches with vessels, tag deployment, vessel movements), procedures should aim to minimize impacts to the extent practicable.

[84] Atlantic Behavioral Response Study: https://www.navymarinespeciesmonitoring.us/reading-room/project-profiles/atlantic-behavioral-response-study/

- Lastly, communication with other researchers and stakeholders can greatly benefit tagging efforts to minimize repeated impacts. This includes sharing lessons learned from previous tagging efforts, utilizing information from local communities, and disseminating results for the greatest scientific benefit. Communication is also important with those who have subsistence, economic, or cultural interest in the study species (e.g., through hunting, whale watching, etc.).

Ultimately, as described in Andrews et al. (2019), animal welfare should be of the highest priority when developing a research plan. Researchers should tag as few animals as possible to address the scientific or management question, as well as minimize the tag invasiveness. Prior to conducting any field work, risk to animals and personnel should be considered, along with actions to reduce or mitigate risk in the field. Risk reduction strategies include training all team members, complying with all legal requirements, and obtaining approval from an ethical board or committee.

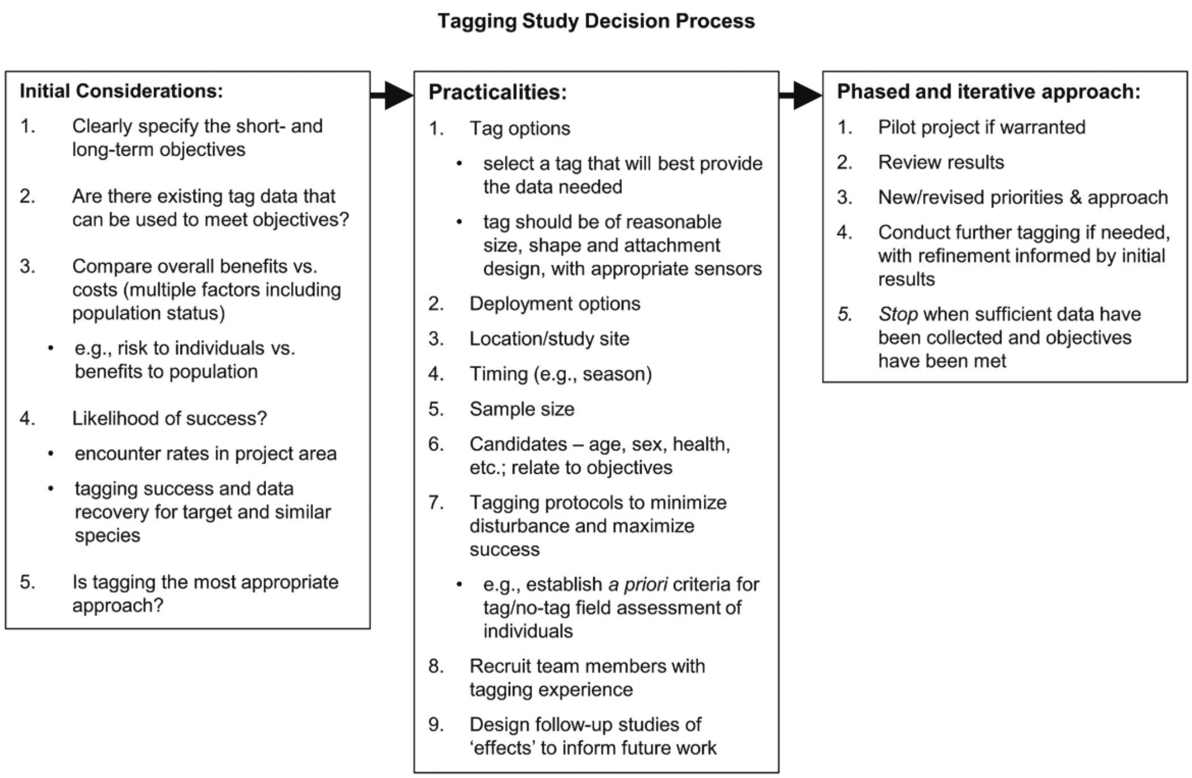

Figure 13. Recommended decision-making process for cetacean tagging studies (from Andrews et al. 2019). See Andrews et al. for additional details, including explanation of what represents a "reasonable" tag design for a given species: https://research-portal.st-andrews.ac.uk/en/publications/best-practice-guidelines-for-cetacean-tagging.

Though best practices and methodologies for safely tagging whales have been used for many species and populations, some at-risk species are of particular concern when considering tagging efforts. The North Atlantic right whale is listed as "Endangered" under the Endangered Species Act and is at risk from multiple anthropogenic stressors, including vessel strikes and entanglements in fishing gear (see *Why are baleen whales dying in the Northwest Atlantic and is this a new phenomenon?*). The population, as of the beginning of 2023, was estimated to be 372 individuals, with only approximately 70 reproductively active females . As such, any further impact to these animals needs to be carefully considered in the context of population status and existing health risks. A workshop was conducted in September 2023 that brought together 52 researchers and government individuals to review key knowledge gaps and data needs to better understand North Atlantic right whale movement and ecology; to review the history of satellite tagging and evaluate how the technology and practice has progressed; and to inform planning and permitting decisions around North Atlantic right whales and other endangered whales. A report from this workshop was published by the Marine Mammal Commission (2024). There were discussions on the efficacy of tagging North Atlantic right whales in the context of the other risk factors they already face, which was weighed against the knowledge gaps in right whale ecology that could be addressed with tagging efforts and the urgent need for more effective management measures to protect this species. Although tagging studies can provide continuous movement data and increase our understanding of whale behavior and habitat use, participants agreed that integration of information from a range of technologies and research methods will be required to fill key knowledge gaps and inform management decisions. Participants also agreed that filling knowledge gaps should not further compromise the health of North Atlantic right whales, so additional discussions involved the potential impacts of tagging on the health, reproduction, and survival of whales, and the need for researchers to use the least invasive techniques to answer specific questions relative to management needs. Recommended next steps from the workshop included the development of a protocol for choosing appropriate animals on which to deploy tags (based on tag type and individual implications); an analysis of tag impacts to date on North Atlantic right whales, particularly focused on health, reproduction, and survival; synthesis of data obtained from previous tagging studies; improvements in methods for assessing whale health after tags are deployed; and improvements in tag design, informed by compiling information on blubber thickness of North Atlantic right whales.

For More Information

- New England Aquarium 2023 blog post, "Tagging Right Whales: Know Your Tag Types": https://www.neaq.org/tagging-right-whales-know-your-tag-types/
- Oregon State University Marine Mammal Institute video: How do we tag a whale? https://mmi.oregonstate.edu/whet/how-do-we-tag-whale

How do marine mammals experience sound differently from humans?

- Humans and marine mammals experience sound differently because air and water have different physical properties that influence sound propagation and because we have different anatomies for hearing and producing sound living above- vs. underwater.
- Sound travels much faster and farther in water than it does in air due to the different densities of the two mediums.
- In general, human and marine mammal hearing are optimized for different frequency ranges.

Detailed answer

The ways humans and marine mammals experience sound (i.e., through perception and production) are distinguished primarily by the medium through which sound travels (air vs. water) and fundamental anatomical differences that determine the kinds of sounds humans vs. marine mammals can hear and produce. Natural sounds have been part of the ocean soundscape for millions of years, and marine mammals have evolved to be acoustic specialists in this environment (Branstetter & Sills 2022). Sound provides an important source of information to marine animals about their surroundings, especially given that many parts of the marine environment have limited visibility. Marine mammals produce a range of sounds associated with behaviors including mating, raising young, social interactions, group cohesion, and feeding (Erbe et al. 2016).

Marine mammals and humans are adapted to receive and produce sound in water (a liquid) and air (a gas), respectively. Though sound behaves as a wave in both environments and can be described with similar terminology (e.g., frequency, intensity, etc.), sound waves move >4 times faster in water because it is a much denser medium than air.[85,86] For similar reasons, sound- especially at low frequencies- can propagate over greater distances in water than in air because it loses less energy as it is transmitted. Oceanographic conditions and water depth, among other factors, can also affect (increase/decrease) the distance sound can travel in water, which makes it challenging to determine exactly how individual marine mammals receive sound underwater.[87,88] Analogous environmental conditions like air temperature, humidity, pressure, and wind direction can affect how far sound can travel in air.[89]

Marine mammal species have different hearing capabilities and are classified into multiple groups based on the frequencies of sounds they produce and hear underwater (Southall et al. 2019; Fig. 1). Marine mammals also have a range of specialized auditory structures and body tissues that are known or postulated components of their auditory systems. In the case of some species, the upper hearing and production ranges of these sounds are in the so-called "ultrasonic" range (>20 kHz), which cannot be heard by humans. By comparison, human hearing (specifically in air) includes frequencies between 0.02-20 kHz (Figure 14), but humans hear best between 1- 5 kHz, where human conversation (i.e., sound production) is centered (Pumphrey 1950, National Research Council 2004).[90] Like marine mammals, human hearing is moderated by sound intensity ("volume"), and we cannot hear frequencies near our upper and lower limits very well unless they are high intensity. In both marine mammals and humans, hearing occurs as sound is received, processed, and translated into neural signals through the outer, middle, and inner ears, but there are significant differences in hearing anatomical structures, especially between humans and cetaceans.[91,92] Baleen whales in particular have specialized structures for optimal hearing at low frequencies.[93]

For more scientific information about marine mammal hearing and ocean-related sound, Discovery of Sound in the Sea (DOSITS, https://dosits.org/) is a useful resource for learning more about these topics. DOSITS is a website developed by the University of Rhode Island's Graduate School of Oceanography in partnership with Inspire Environmental of Newport, RI, with contributions from independent scientific reviewers and Rhode Island school teachers.

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85 The Discovery of Sound in the Sea (DOSITS) Sound in Water vs. Air: https://dosits.org/science/sounds-in-the-sea/how-does-sound-in-air-differ-from-sound-in-water/

86 DOSITS How to characterization sound: https://dosits.org/science/sound/characterize-sounds/

87 DOSITS How fast does sound travel?: https://dosits.org/science/movement/how-fast-does-sound-travel/

88 DOSITS How does sound travel long distances?: https://dosits.org/science/movement/sofar-channel/sound-travel-in-the-sofar-channel/

89 NASA Glenn Research Center Speed of Sound Interactive: https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/speed-of-sound-interactive/#speed-of-sound

90 DOSITS What sounds can people hear?: https://dosits.org/science/measurement/what-sounds-can-we-hear/

91 DOSITS Hearing in marine mammals: https://dosits.org/animals/sound-reception/marine-mammals-hear/hearing-in-cetaceans/

92 DOSITS Hearing in land mammals (humans): https://dosits.org/animals/sound-reception/marine-mammals-hear/land-mammals/

93 DOSITS Low frequency sound and marine mammals: https://dosits.org/animals/advanced-topics-animals/low-frequency-sound-production-and-reception-in-mammals/

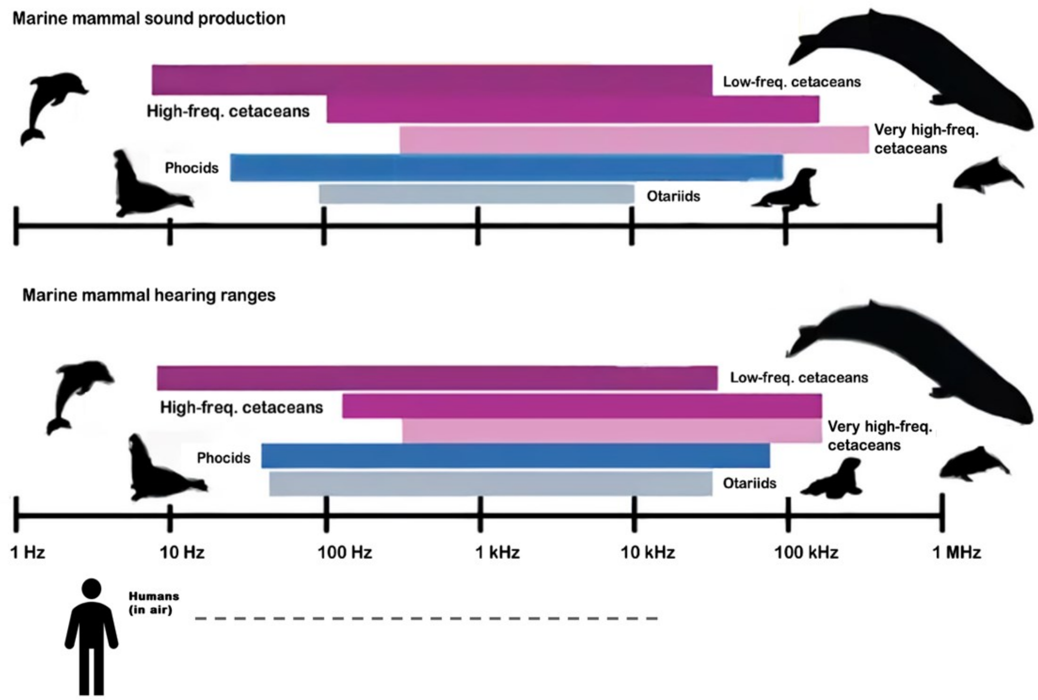

Figure 14. Sound frequency ranges (units in Hz) for selected marine mammal and human hearing ranges (lower panel) and sound production (upper panel). Figure excludes sirenians, polar bears, and otters. Low-frequency cetaceans include baleen whales; high-frequency cetaceans include bottlenose and common dolphins, killer and pilot whales, sperm whales, and beaked whales; very high-frequency cetaceans include porpoises and freshwater dolphins. Adapted from original diagrams by C3P0Lab and NOAA Fisheries.

For More Information

- DOSITS Webinars: https://dosits.org/decision-makers/webinar-series/
- NOAA Fisheries, Sounds in the Ocean (Mammals): https://www.fisheries.noaa.gov/national/science-data/sounds-ocean-mammals#more-information
- NOAA, Marine Mammals and Noise Fact Sheet: https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/GOMR/Marine-Mammals-And-Noise-Fact-Sheet.pdf

What are Protected Species Observers and what data do they collect about marine mammals?

- Protected Species Observers (PSOs) are trained professionals who monitor marine animals that are federally protected under the Endangered Species Act (ESA) and/or Marine Mammal Protection Act (MMPA). This monitoring occurs in relation to anthropogenic activities and helps a wide range of entities comply with federal requirements.
- There is a certification process and standards for PSO training, and credentials of individuals are reviewed by NOAA Fisheries for specific projects to ensure they have appropriate training and/or experience to perform the necessary duties.

- PSOs collect data to inform implementation of marine mammal mitigation measures for a variety of activities associated with offshore wind energy development and to enhance the understanding of potential offshore wind impacts on marine mammals. Data include sightings of live, entangled, or dead marine mammals; marine mammal sightings to inform implementation of a mitigation measure (such as changing a vessel speed/trajectory or shutting down a sound-generating activity when animals are present in the vicinity); a record of PSO observation effort and methods; and offshore wind farm operations data (e.g., project name, location, details about active acoustic sources).
- The federal agencies who receive PSO data and reports from offshore wind projects include NOAA Fisheries, the Bureau of Ocean Energy Management (BOEM), and the Bureau of Safety and Environmental Enforcement (BSEE).

Detailed Answer

Protected Species Observers (PSOs) are trained professionals who monitor for marine animals that are federally protected under the Endangered Species Act (ESA) or Marine Mammal Protection Act (MMPA; see *What federal and international environmental laws protect whales?*). The overarching goal for PSOs is to assist in efforts to minimize or eliminate impacts of human activities on protected species for various entities to meet their regulatory compliance needs.[94] PSOs monitor construction, demolition, pile driving, detonations, geophysical and seismic surveys, and military activities, among others. Protected marine species include all species of marine mammals, all species of sea turtles, and species of manta rays, sharks, salmonids, and sturgeon that are ESA-listed.

PSO duties include monitoring during sound-generating activities to detect marine mammals that are in the vicinity (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?* and *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*) and direct the implementation of applicable mitigation measures for such activities, when needed. Data from PSOs also help federal agencies evaluate the effectiveness of mitigation and monitoring efforts. The results from PSO data may lead to revised mitigation or monitoring measures for existing projects, assist in the development of mitigation and monitoring measures for future projects, or contribute to efforts to better understand the impacts or benefits of anthropogenic projects in the marine environment (BOEM 2024d).

To become a PSO, an individual must undertake specialized training and be approved by NOAA Fisheries (Baker et al. 2013). NOAA Fisheries reviews the credentials of potential PSOs to determine whether they have the appropriate training or experience to perform the necessary project-specific duties. PSO training includes identification of marine mammals, sea turtles, and other protected species; understanding of legislative and regulatory requirements; vessel strike avoidance and reporting protocols; how and when to communicate with the vessel captain; information about the authority of the PSOs to change or halt project operations to protect animals; and how to implement all required mitigation measures effectively. PSOs are independent observers and therefore are not direct employees of the entity utilizing their service.

The federal agencies that designate PSO qualifications, duties, and other operational and reporting protocols for particular activities related to offshore wind energy include NOAA Fisheries, BOEM, and U.S. Fish and Wildlife Service. Detailed information about PSO duties for individual projects are designated in various federally-issued permits, authorizations, and approvals for those projects, such as incidental take

[94] More information on PSOs: https://www.fisheries.noaa.gov/national/endangered-species-conservation/protected-species-observers

authorizations (required under the MMPA), construction and operations approvals, lease requirements, and Environmental Impact Statements (required under the National Environmental Policy Act; for more information about these regulatory and permitting documents, see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*).[95] PSO duties may include:

- Monitoring for marine mammals approaching or within certain distances of activities, such as geophysical surveys and impact and vibratory pile-driving. Authorizations typically require a pre-specified clearance and/or shutdown zone around such activities, and the activity will be delayed or will cease if a PSO reports a protected animal within the relevant zone (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?* for more details on clearance, shutdown, and vessel-strike avoidance zones).
- Monitoring for marine mammals in the vessel strike avoidance zone.
- Reporting sightings of North Atlantic right whales to NOAA Fisheries, U.S. Coast Guard, BOEM, BSEE, and the WhaleAlert app.[96]
- Reporting sightings of dead, injured, and entangled marine mammals to the NOAA Fisheries stranding hotline.
- Collecting and reporting data on all marine mammals observed and for which mitigation was implemented.
- Communicating relevant information with project and vessel crews. This includes ordering the crew to shut down activities, if necessary, based on the requirements of the authorizations.

PSOs are used for mitigation monitoring of sound-generating offshore wind development activities (e.g., site assessment surveys, turbine installation; see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*). The types of data that PSOs collect for activities associated with offshore wind development include sightings and detections of all observed marine mammals for mitigation purposes (e.g., date, time, geographic location, species, total number of individuals in a group/pod, age class, behavior, distance and bearing to the sighting), observation effort (e.g., duration and location of monitoring, monitoring method, environmental conditions that may affect detectability), and operations (e.g., details about active acoustic sources, including hours of activity, to provide context for the level of disturbance; mitigation implementation; Ganley et al. 2024). The particular data fields that PSOs need to record and the reporting requirements are specific to each project and are comprehensively detailed in the project's Construction and Operations Plan Approval letter and in Incidental Take Authorizations. For an example of a comprehensive list of the data types collected by PSOs for offshore wind construction, see BOEM (2023).

Data collected by PSOs are required to be submitted to federal agencies, including NOAA Fisheries, BOEM, and BSEE. Incidental Take Authorizations require PSO data be summarized in monitoring reports to NOAA Fisheries[97], for example. However, they do not require the underlying data to be made publicly available, an issue that was noted in a recent study that tried to use PSO data to better understand whale distributions (Ganley et al. 2024). Federal agencies receive and archive the data, but inconsistencies in these data make them difficult or impossible to use in broader analyses at present (Ganley et al. 2024).

[95] Central Atlantic Offshore Wind Activities: https://www.boem.gov/renewable-energy/state-activities/central-atlantic

[96] Whale Alert: https://www.fisheries.noaa.gov/resource/tool-app/whale-alert

[97] Available at: https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable

BOEM is currently funding the development of a PSO database[98] to better organize these data for use in broader research and analysis efforts.

Can publicly available data and reports from Protected Species Observers (PSOs) help improve our understanding of marine mammal populations?

- Protected Species Observers (PSOs) are trained professionals who implement a range of mitigation and monitoring measures to reduce impacts to protected species from human activities. PSOs also collect data to support broader federal agency goals (e.g., recording sightings of live, entangled, or dead marine mammals). While the main focus of PSOs is to monitor for protected species and implement mitigation measures, as required, PSO data can also theoretically be used to help inform our understanding of species presence, abundance, and distributions, though limitations exist on the utility of this data for broader research purposes.
- A recent scientific publication (Ganley et al. 2024) examined publicly available PSO data related to offshore wind energy development from 2017–2022 and indicated that data formatting and reporting protocols were not standardized; therefore, PSO data could not be used to meet broader scientific goals.
- Data formatting and standardization processes for PSO data reporting have improved since 2022. Offshore wind developers are required to submit all PSO datasets and summary reports to NOAA Fisheries. However, not all data have been made publicly available on the NOAA website (as of November 2024).
- Additional standardization and public data access are still needed to better allow PSO sightings and effort data to fill knowledge gaps regarding marine mammal habitat and distribution. The Bureau of Ocean Energy Management (BOEM) is currently funding the development of a PSO database to better organize these data for use in broader research and analysis efforts.

Detailed Answer

Protected Species Observers (PSOs) are trained professionals who monitor for marine animals that are protected under the U.S. Endangered Species Act (ESA) or Marine Mammal Protection Act (MMPA), which includes marine mammals, sea turtles, and protected fish species. The overarching goal of PSOs is to reduce impacts to protected species from human activities such as construction, demolition, geophysical and seismic surveys, and military activities (see *What are Protected Species Observers and what data do they collect about marine mammals?*). Data collected by PSOs are focused on implementing mitigation and monitoring measures, such as delaying or shutting down sound-generating activities or implementing vessel strike avoidance measures when protected animals are in the vicinity (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*). PSOs also report sightings not associated with the specific activity being monitored, such as sightings of entangled protected animals, protected animals exhibiting signs of vessel strike, or dead protected animals.

PSO data are intended to (1) help federal agencies evaluate whether mitigation and monitoring measures are implemented appropriately and assess relevant permit compliance; (2) help federal agencies evaluate the effectiveness of those measures; (3) inform the development of mitigation and monitoring measures for future projects; and (4) contribute to efforts to better understand the impacts or benefits of anthropogenic projects in the marine environment (Baker et al. 2013, BOEM 2024d, NOAA 2024). Need to

[98] Protected Species Database and Information Management: https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/Protected%20Species%20Database%20and%20Information%20Management.pdf

link PSO data can also theoretically be used to help inform our understanding of species presence, abundance, and distributions (Baker et al. 2013, BOEM 2024d, NOAA 2024), though they have some limitations for this type of broader analysis. For more information, see *What are Protected Species Observers and what data do they collect about marine mammals?*

To understand the utility of PSO data specific to offshore wind activities, Ganley et al. (2024) reviewed 14 Incidental Harassment Authorizations (IHAs) issued for offshore wind site assessment geophysical surveys in wind energy areas off Massachusetts and Rhode Island between 2017 and 2022, and all 10 of the associated monitoring reports that were publicly available as of October 2022. The authors were particularly interested in determining whether publicly available PSO data could be used to fill knowledge gaps related to marine mammals and offshore wind activities, including habitat use, distribution, abundance, environmental variables that may drive or be associated with marine mammal distribution patterns, and animal responses to the construction and operation of wind energy areas. They found that it was not possible to develop species distribution models using the PSO data due to lack of public access to the actual data at that time; summary reports were public, but the underlying data were not publicly available. In addition, the PSO data they examined exhibited inconsistent and inadequate data collection and reporting procedures. Although IHAs required collection of a common set of data fields, the IHAs at that time did not specify formats for recording or reporting the data. As a result, the data were recorded in a range of formats (e.g., different time zones, latitude and longitude formats, best estimates of group size vs. high and low estimates, etc.) and were reported in a variety of ways, including maps and different table designs.

BOEM and NOAA Fisheries have revised their data standards and formats in more recent years for completeness and consistency across offshore wind permits. More PSO datasets from individual offshore wind projects are public than at the time that the Ganley et al. (2024) analysis was conducted (though as of November 2024, some PSO datasets were still not publicly available on NOAA's website). BOEM is currently funding the development of a PSO database[99] to better organize these data for use in broader research and analysis efforts.

What marine mammal-related monitoring is conducted by offshore wind developers and what resulting data are public?

- There are various ways in which offshore wind developers may be involved with research and monitoring, including (1) monitoring for the purposes of mitigation and (2) monitoring and research to understand baselines and potential effects, which may be funded by individual developers or other groups, for which developers contribute site access, staff time, and/or other resources.
- Major types of marine mammal monitoring and research activities conducted in relation to offshore wind energy development include passive acoustic monitoring (PAM), use of Protected Species Observers (PSOs), near-real time incidental reporting of important sightings, boat-based and aerial surveys, biologging (e.g., individual tracking using GPS tags or other transmitters), and biological sampling.
- Federal agencies, state agencies, and regional science groups generally recommend that all marine mammal data collected by developers be made publicly available. Monitoring data

[99] Protected Species Database and Information Management: https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/Protected%20Species%20Database%20and%20Information%20Management.pdf

collected as part of federal permitting are shared with federal agencies and made publicly available. However, data sharing can be complicated in cases where there is no public database for a particular type of data.

Detailed Answer

Types of Monitoring and Research

There are various ways in which offshore wind developers are involved in monitoring and research related to marine mammals. The most common is monitoring required as part of conditions under federal permits and authorization for the purposes of mitigation (see *What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?*). In addition, offshore wind energy developers may also conduct a range of monitoring and research activities before, during, and after offshore wind facilities are constructed with goals of understanding baseline marine mammal abundance and distribution to inform risk assessments and potential effects of wind farm development and operations on marine mammals (see *What are the potential effects of offshore wind development on whales?*). The specific methods, timing, and other details vary depending on the objectives (see *How do scientists study whales?*). In cases where monitoring is conducted as part of permitting conditions (primarily monitoring for the purposes of mitigation), methods are typically agreed upon by the developer and federal regulatory agencies during the permitting process, sometimes with input from other federal or state agencies, nonprofit environmental organizations, or other entities. Final project-specific mitigation monitoring requirements are outlined in federal permitting documents such as Incidental Harassment Authorizations issued by NOAA Fisheries and Conditions of COP (Construction and Operations Plan) Approval issued by the Bureau of Ocean Energy Management (BOEM) before an offshore wind project can begin construction.

Other types of monitoring and research activities, which may or may not be required by regulators, include those that are conducted by offshore wind developers and other entities, such as federal agencies, state agencies, or regional entities, with which offshore wind developers collaborate to understand potential effects of offshore wind development on marine mammals. As collaborators, offshore wind developers may help coordinate site access for the deployment of equipment, along with support via personnel or vessel time. The Regional Wildlife Science Collaborative for Offshore Wind maintains a database of ongoing marine mammal-related research conducted by various entities, including offshore wind developers.[100]

Major types of marine mammal monitoring and research activities conducted in relation to offshore wind energy development include visual observations via systematic survey or Protected Species Observers (PSOs), passive acoustic monitoring (PAM), biologging (e.g., individual tracking using tags), and biological sampling (see *How do scientists study whales?*, *What are Protected Species Observers and what data do they collect?*). Such methods are more focused on mitigation of impacts during specific activities (e.g., PSOs during pile-driving) while others are more commonly used to provide additional information on marine mammal presence and movements to inform offshore wind energy development and better understand potential impacts.

These data collection methods may each be used during different phases of offshore wind energy development and for different purposes. For example, PAM can occur in near-real time to detect whales during activities such as construction of turbine foundations and to help inform mitigation actions such as temporary shutdown of pile driving while animals are in the vicinity. Longer-term archival PAM can be

[100] Regional Wildlife Science Collaborative Offshore Wind and Wildlife Research Database: https://database.rwsc.org/

used to assess baseline presence levels of whales prior to development and to assess changes in species presence and acoustic activity before, during, and after construction.

Monitoring Plans, Reporting, and Data Availability

There are various plans that must be developed for monitoring for the purposes of mitigation required under permitting conditions. These include Pile Driving Monitoring, Mitigation and Management Plans that include data collection and reporting details for the visual and PAM components of marine mammal monitoring that are conducted PSO and PAM operators (see Tetratech 2024 as an example). If the developer proposes to conduct pile-driving operations at night or in low-visibility weather, an Alternative Monitoring Plan is required that specifies additional compliance measures (BOEM 2024d). They are also required to develop a Vessel Strike Avoidance Plan (see DEME Offshore US 2024 as an example). There are also instances where states, under power purchase agreements, also require additional mitigation and monitoring plans to be developed.[101]

Once monitoring plans have been implemented, developers are required to submit an annual monitoring report to federal agencies for all protected species monitoring[102]; this report includes methods, protocols, and estimates of numbers of animals exposed to project activities.[103] Reports must also be accompanied by the actual data collected (e.g., raw sightings and survey tracklines; BOEM 2024b).[104] In addition to annual reporting, some types of activities (as well as incidental reporting of observations of ESA-listed species) must be reported to federal agencies much more frequently (within days to weeks; BOEM 2024b). For example, if offshore wind energy developers or their contractors detect a North Atlantic right whale, it must be reported to multiple federal agencies within 24 hours (NOAA 2022a, BOEM 2024e, a d). Likewise, if a marine mammal is sighted and determined to be injured, entangled in fishing gear, or dead (regardless of the cause of injury or death), a report must be submitted to federal agencies within 24 hours that includes a range of information to help the agencies decide how best to proceed with assessment and recovery operations (BOEM 2021, 2022a, 2024e a).

Data collected by offshore wind energy developers under permitting conditions are required to be shared with federal regulatory agencies. What data must be shared, and on what timeline, is variable by data type and has changed over time as federal agencies have refined their requirements of developers. Thus, data sharing requirements may vary between individual offshore wind projects, particularly when comparing early projects to more recent projects. Recent permitting documents from BOEM recommend that all wildlife monitoring data be made public (BOEM 2024d). It is also recommended that data collection and sharing meet the standards outlined by regional science entities such as the Regional Wildlife Science Collaborative for Offshore Wind (RWSC), which operates in the eastern U.S. (RWSC 2024). For example, the Marine Mammal Subcommittee of the RWSC has provided recommended best practices for offshore wind-related PAM data management and storage (RWSC 2022). These standards typically recommend that developers submit datasets to existing databases and data portals that are structured to share data publicly. For some types of data, however, there is no public database designed to serve data back to the public. For passive acoustic monitoring (PAM) data, federal regulators require the offshore wind energy developer to submit data to the agencies as well as to the National Centers for Environmental

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[101] For example, New York State requirements the development of Environmental Mitigation Plans: https://www.nyetwg.com/e-twg-activities/environmental-mitigation-plans

[102] For more information on the public availability of these reports, see Can publicly available data and reports from Protected Species Observers (PSOs) help improve our understanding of marine mammal populations?"

[103] Incidental Take Authorizations for Other Energy Activities (Renewable/LNG): https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable

[104] Incidental Take Authorizations for Other Energy Activities (Renewable/LNG): https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable

Information (NCEI) for archiving and use in broader regional scientific analyses (BOEM 2024d), but not all data submitted to NCEI is currently publicly available. Likewise, PSO data is required to be submitted to NOAA Fisheries and BOEM. Although the raw data are in some cases available on NOAA Fisheries' website (see *Can publicly available data and reports from Protected Species Observers (PSOs) help improve our understanding of marine mammal populations?*), there is no single database for these data yet (though one is currently in development).[105] In addition, there has been variation in data format across projects (Ganley et al. 2024), though the federal agencies have worked to standardize data reporting requirements in recent years. Other recommendations for environmental data sharing for offshore wind energy development (e.g., NYSERDA 2021) recommend that all data be made public within two years of collection, where possible, and that developers serve the data directly (for example, on their public websites) if there is not a suitable database available to house them.

In addition to federal requirements and recommendations, states like New York, New Jersey, Massachusetts, and Connecticut also have recommendations or requirements for offshore wind developers to share their data (e.g., NYSERDA 2021). In some cases, states include requirements for data sharing in their power purchase agreements with developers. States may also impose specific mitigation and monitoring requirements in addition to those required by federal agencies, though state jurisdiction over offshore wind facilities in their waters may vary by state. For example, several states require offshore wind energy developers that sell power to their state to provide between $5,000 and $10,000 per MW of wind farm capacity for research and monitoring separate from any activities the developers themselves must undertake in relation to federal permitting. In the case of monitoring and research conducted voluntarily by offshore wind developers either alone or in collaboration with other entities, public data sharing is encouraged.

For more information

- Regional Wildlife Science Collaborative for Offshore Wind: https://rwsc.org/
- Wind Energy and Marine Mammals: https://windexchange.energy.gov/projects/marine-mammals

Offshore Wind Regulatory Processes and Mitigation

What federal and international environmental laws protect whales?

- The Marine Mammal Protection Act, Endangered Species Act, and National Environmental Policy Act protect marine mammals in U.S. waters. The International Whaling Commission and the Convention on International Trade in Endangered Species of Wild Fauna and Flora also regulate human activities around marine mammals and endangered species.
- During the offshore wind development process, the Bureau of Ocean Energy Management oversees multi-year, multi-step regulatory processes mandated under the above federal regulations.
- Some number of "incidental takes" of marine mammals may be permitted during the offshore wind development process; "take" means that there is a disturbance of a marine mammal, however minor in scale (See *What is take?*). Offshore wind companies are not issued permits for take in which an animal is killed or injured beyond the point of recovery.

[105] Protected Species Database and Information Management: https://www.boem.gov/sites/default/files/documents/environment/environmental-studies/Protected%20Species%20Database%20and%20Information%20Management.pdf

Broad answer

The **Marine Mammal Protect Act** (MMPA) established a national policy to prevent at-risk marine mammal populations from "diminishing to the point where they are no longer a significant functioning element in their ecosystem", or if they "fall below an optimum sustainable population size". The MMPA charges the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (i.e, NOAA Fisheries) with the responsibility to protect whales, dolphins, porpoises, seals, and sea lions. The MMPA also established the Marine Mammal Commission (MMC), a separate federal agency that provides independent oversight of marine mammal-related policies and programs carried out by other federal agencies.

The **Endangered Species Act** (ESA) establishes national regulations for the prevention of harm to endangered species or species likely to become endangered, as well as their habitats. Section 7 of the ESA requires other federal agencies to consult with NOAA Fisheries if they are proposing an action that may impact ESA-listed marine mammal species or habitats.

The **National Environmental Policy Act** (NEPA) requires federal agencies to consider and assess the environmental impacts of proposed actions. Activities including offshore wind development often require Environmental Impact Statements (EIS) or Environmental Assessments (EAs) to determine the impact on marine mammals prior to development.

The International Whaling Commission (IWC) is the international entity created to conserve and manage whales and whaling worldwide. The IWC's work includes coordinating and funding research and conservation efforts directed towards whales, dolphins, and porpoises; analyzing data to estimate population abundance and undertaking technical review of existing abundance estimates; investigating stock structure; maintaining scientific databases; and setting quotas for indigenous subsistence whaling.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates international trade of endangered species and issues trade permits based on certain criteria, including the determination that an export of a specific species will not threaten its survival.

During the offshore wind development process, the Bureau of Ocean Energy Management (BOEM) oversees multi-year, multi-step regulatory processes, mandated under NEPA, the MMPA, and the ESA. These processes include consultation with other agencies, including NOAA Fisheries, the assessment of potential effects to marine mammals, and the minimization and/or mitigation of impacts. NOAA Fisheries may allow some number of "incidental takes" of marine mammals during the offshore wind development process; take means that there is a disturbance of a marine mammal, however minor in scale (see *What is take?)*. The agency does not issue offshore wind companies permits for take in which an animal is killed or injured beyond the point of recovery. They will allow some level of "incidental harassment," however, in which there is the potential to temporarily disturb or injury a marine mammal.

Detailed answer

There are three federal laws in the U.S. that protect whales, including the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and National Environmental Policy Act (NEPA). During the offshore wind development process, a federal agency, the Bureau of Ocean Energy Management (BOEM), oversees multi-year, multi-step regulatory processes that include consultation with other agencies, including NOAA Fisheries. These regulatory processes require an assessment of potential effects of offshore wind to marine mammals, as well as minimization or mitigation of impacts. There are also several international entities that manage marine mammals, including the International Whaling Commission (IWC) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

NEPA

The National Environmental Policy Act (NEPA), enacted in 1970, requires federal agencies to consider environmental impacts of their proposed actions. NEPA is intended to be "a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation" (42 U.S.C. §4321(a.). Though NEPA does not provide explicit protection for marine mammals, it does establish a framework that ensures federal agencies take environmental considerations into account when making decisions that may impact certain species and their environment.

The cornerstones of the NEPA process are Categorical Exclusions, Environmental Assessments (EAs), and Environmental Impact Statements (EISs). Categorical exclusions are granted to certain types of actions that a federal agency has previously determined do not normally have a significant effect on the human environment. EAs are not as comprehensive as EISs. An agency may prepare an Environmental Assessment (EA) if there is uncertainty about whether the proposed action will have a significant environmental impact and may prepare an EIS only if it is deemed necessary (Vann 2023). If proposed agency actions are expected to significantly affect the environment, the preparation of an EIS is required. An EIS contains a detailed analysis of the project and/or action that is proposed as well as any alternatives. Once an EA or EIS is drafted, there is a period during which the public may comment on the agencies' findings. All offshore wind energy development projects to date (as of 2024) have included the preparation of EISs.

The Council of Environmental Quality, established under Section 2, ensures federal agencies meet their obligations under NEPA by (1) overseeing implementation of the environmental impact assessment process, and (2) issuing regulations and other guidance to federal agencies regarding NEPA compliance.

Data and information gathered through the NEPA process can help inform regulatory decisions that can lead to mitigation of impacts on marine mammals. Categories of mitigation measures under NEPA include:

- *Avoiding* the impact altogether by not taking a certain action or parts of an action.
- *Minimizing* impacts by limiting the degree or magnitude of the action or adjusting its implementation.
- *Rectifying* the impact by repairing, rehabilitating, or restoring the affected environment.
- *Reducing* or eliminating the impact over time; and
- *Compensating* for the impact by replacing or providing substitute resources or environments.

MMPA

The U.S. Marine Mammal Protection Act (MMPA) was passed in 1972 as a response to declining marine mammal populations that were in danger of extinction due to human activities. The MMPA established a national policy to prevent at-risk marine mammal populations from "diminishing so they are no longer a significant functioning element in their ecosystem, or so they fall below an optimum sustainable population size" (16 U.S.C. §1361). The MMPA was the first piece of U.S. legislation that focused on an ecosystem management approach. It charged three federal entities with its implementation:

- NOAA Fisheries – Responsible for protection of whales, dolphins, porpoises, seals, and sea lions;
- U.S. Fish and Wildlife Service (USFWS) – Responsible for protection of walrus, manatees, sea otters, and polar bears; and
- The Marine Mammal Commission – An independent federal agency that provides oversight of the marine mammal-related policies and programs of other federal agencies.

The MMPA requires annual assessments of stocks (i.e., stock assessment reports) that include, but are not limited to, estimates of population size, potential biological removal (PBR) level, and the number of anthropogenic mortalities or serious injuries (M/SI) imparted on stocks by various sources (e.g., commercial fisheries). Guidelines exist for determining human causes of mortality and for defining and determining mortality vs. serious injury to help standardize reporting.[106] The calculation of M/SI is then compared to the value of PBR. If M/SI is lower than PBR, the anthropogenic influence on the stock is judged to not be occurring at a level that warrants federal action. If M/SI is greater than PBR, there are anthropogenic causes of death that are occurring at a level that could impact the stock success, and it is designated as a strategic stock.

If M/SI exceeds PBR due to impacts from fisheries (e.g., bycatch, entanglement in gear), the MMPA requires that a "take reduction team" is formed to recover and prevent future depletion of marine mammal stocks due to fisheries interactions. Within six months of implementation, the goal is to reduce fisheries-induced M/SI to less than the PBR level. In the long term, the goal is to approach a rate of zero fisheries-induced mortality. Take reduction teams consist of members of the fishing industry and fishery management councils, state and federal agencies, the scientific community, and conservation organizations.

The abundance estimates published in marine mammal stock assessment reports may be used to determine the number of non-lethal human interactions that a particular activity or project may be permitted to "take". Take means that there is an intended or unintended disturbance of a marine mammal, however minor in scale; it does not necessarily mean that an animal is killed or injured beyond the point of recovery (see *What is take?*). Importantly, the concept of take is meant to limit harmful effects of human interactions with marine mammals. The MMPA creates a framework for the general prohibition of "take" of marine mammals; however, there are allowances for exemptions via take permits in certain situations (i.e., hunting for indigenous subsistence; harassment from energy infrastructure; intentional and incidental harassment for scientific research and other situations).

Incidental take permits are one of the categories of permits under the MMPA. Incidental takes are defined as unintended (but not unexpected) takes,[107] and may be authorized upon request. This is the category of permits for which offshore wind developers submit applications to allow a small number of marine mammals to be harassed for select activities in specific places. The authorization of incidental take may be granted if, after public comment, it is found that:

- Impacts are small in number;
- Impacts are negligible (to species or stocks);
- Impacts will not cause disruption to the availability of select marine mammals for indigenous subsistence purposes (and/or mitigation measures are proposed to increase the presence of marine mammals for subsistence purposes to offset these effects); and
- NOAA prescribes the permissible method of take, mitigation measures, and requirements for monitoring and reporting.

[106] More information: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports and https://media.fisheries.noaa.gov/dam-migration/02-238-01.pdf

[107] NOAA Incidental Take definition: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act

Important Definitions Under the Marine Mammal Protection Act (MMPA)

The following definitions under the MMPA are important for understanding how, and when action or intervention is necessary for the protection of marine mammals.

Stock – A group of marine mammals of the same species or subspecies that occupy similar spatial regions and interbreed when mature (e.g., the humpback whales that inhabit the waters off the U.S. east coast and west coast belong to different stocks).

Optimum sustainable population – For any given stock, this is the optimal number of animals to maintain the maximum productivity of the population, where productivity is calculated based on the habitat's quality and carrying capacity (i.e., the maximum number of animals the habitat can support indefinitely without causing permanent damage to the habitat).

Potential biological removal (PBR) - The maximum number of animals that can be removed from a stock due to human causes while still maintaining an optimal sustainable population. PBR is reported as a single number for each stock. It is calculated based on stock size, population growth rate, and a recovery factor that accounts for uncertainty in measurements and decisions based on expert discretion (e.g., recovery is impacted if mortality is differentially impacting female vs. male members of a stock).

Strategic stock – A stock becomes strategic when the level of direct human-caused mortality is greater than PBR (e.g., more animals are removed due to human causes than is sustainable). A stock may also be determined as strategic if it is expected to be listed as "threatened" under the Endangered Species Act or is currently listed as "threatened" or "endangered" (see Endangered Species Act section for more information), or is determined to be "depleted" under the MMPA.

Take – "To harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. 1362). Take can be lethal or nonlethal, and can be intentional (e.g., whaling) or incidental (e.g., unintentionally occurring as a result of some other activity, such as energy development).

Harassment – "Any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal (Level A) or disturb a marine mammal by causing disruption of behavioral patterns (Level B)" (16 U.S.C. 1361-1407).

Negligible – Impacts are not expected to, and are not reasonably likely to, negatively impact the survival and reproductive success of a species or stock.

Take under the MMPA is authorized either through a Letter of Authorization (LOA) or an Incidental Harassment Authorization (IHA). An LOA authorizes Level A or Level B harassment that is planned to occur for multiple years, while an IHA authorizes Level A or B harassment for activities planned for a year or less (16 U.S.C. §1373). The MMPA was amended in 1992 and 1994. One of the amendments introduced the Marine Mammal Health and Stranding Response Program. This program permits emergency responses to dead or distressed marine mammals, monitoring of health trends, and investigation of Unusual Mortality Events (UMEs). In addition, these amendments further delineated the different levels of human impacts to marine mammals (the introduction of Level A and Level B harassment categories; see above), introduced exemptions for harassment for certain human activity including indigenous subsistence hunting and scientific research, and introduced the requirement for federal agencies to prepare reports on the status of each marine mammal stock in U.S. waters (Stock Assessment Reports), among other changes. The issuance of incidental take authorizations under the MMPA, when that take is for endangered species, is a federal action that requires ESA Section 7 consultation, as described below.

ESA

Passed one year after the MMPA in 1973, the U.S. Endangered Species Act (ESA) protects endangered species and those identified as *likely to become* endangered in the future.[108] The ESA was created with the intention of protecting endangered species as well as the ecosystems they depend on. Species are either listed as "Endangered" (in danger of extinction throughout all or a significant portion of its range) or "Threatened" (likely to become endangered within the foreseeable future; 16 U.S.C. §1531).

Once a species is listed under the ESA, that species receives legal protection, and it becomes illegal to take individuals (where take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct"). As with the MMPA, the ESA defines incidental take as unintentional, but not unexpected, take. Federal agencies are required to consult either USFWS or NOAA Fisheries if their proposed activities may affect an ESA listed species, including whales. NOAA Fisheries is the executing agency that aids in the determination of whether certain actions will threaten a specific whale species or habitat. Under Section 7(a)(1), an agency proposing to undertake an action that may impact whales that are listed as threatened or endangered must consult with NOAA Fisheries to determine whether a listed species is or will be present in the proposed project area.

Furthermore, the USFWS and NOAA Fisheries, acting through the ESA, can determine and designate critical habitat areas for listed species, including marine mammals. Critical habitat has a very specific definition under the ESA and may only be formally designated to support the recovery of a listed species following extensive analysis and public comment. Once critical habitat is designated, other federal agencies must consult with either the USFWS or NOAA before completing any actions in that area to ensure no harm is done to the critical habitat.

Under the ESA, offshore wind projects are typically required to go through a consultation process between BOEM and NOAA (and the USFWS, as applicable), which must include:

- Information on the proposed action.
- Information about the ecological entities (listed species, critical habitat, etc.).
- An assessment method that integrates this information to produce and support a conclusion; and
- Written record of the interactions, deliberations, or analysis that occurred during the consultation process, the information that was (or was not) considered, and any resolution of disagreement (BOEM 2018).

The ESA, NEPA, and the MMPA interact during the offshore wind energy development process such that there are multiple periods for inter-agency consultation and coordination to minimize and mitigate effects of the development actions on whales (Figure 15).

[108] The International Union for Conservation of Nature (IUCN) also maintains a global "Red List of Threatened Species" (https://www.iucnredlist.org/) that categorizes the conservation status of species and population stocks. This is where terms such as "critically endangered" come from. IUCN definitions of these terms do not necessarily match the definitions in the ESA. Likewise, IUCN assessments of the status of individual species may vary from ESA listing status in the U.S.

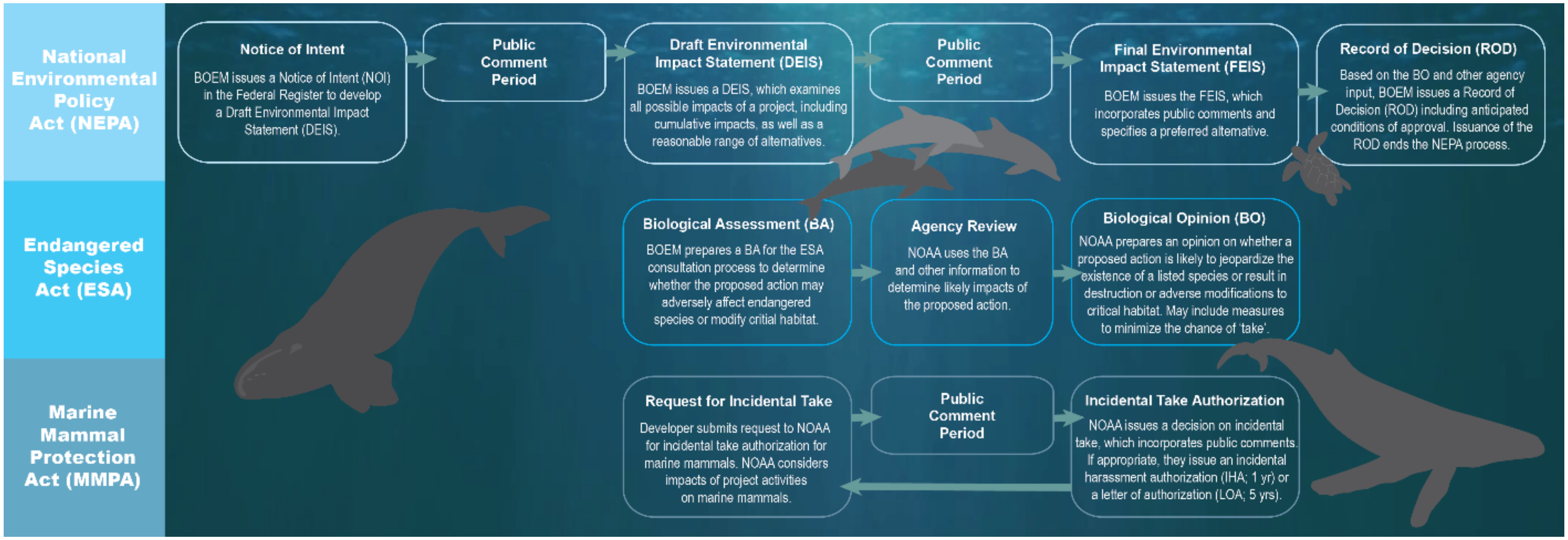

Figure 15. Key U.S. environmental laws protecting whales, and the major steps involved in implementing regulatory assessments and mitigation measures for offshore wind under each law. The steps described in this graphic focus on the steps in the permitting process following site assessment as well as those during construction of offshore wind developments. The MMPA process will occur multiple times as projects are developed (to include different activities and time periods. Source: Biodiversity Research Institute

International Regulations

There are several international regulations that relate to marine mammals, though these do not always directly inform how marine mammal populations are managed in U.S. waters. The International Whaling Commission (IWC), established in 1946 under the International Convention for the Regulation of Whaling (161 UNTS 72, 62 Stat. 1716, TIAS 1849), meets regularly to review scientific, management, and conservation issues that are relevant to whales. The Commission may (1) encourage, recommend, or if necessary, organize studies and investigations relating to whales and whaling; (2) collect and analyze statistical information concerning the current condition and trend of the whale stocks and the effects of whaling activities thereon; and (3) study, appraise, and disseminate information concerning methods of maintaining and increasing whale stocks (e.g., whale populations). A particularly significant action taken by the IWC was the implementation of a moratorium on commercial whaling. Issued in 1986, the moratorium aimed to allow for the recovery of whale populations decimated from commercial whaling throughout the 20th century. All but a few countries in the world (i.e. Norway, Iceland, and Japan) are bound by and comply with this moratorium.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments drafted in 1973. CITES aims to ensure that any international trade of listed flora and fauna does not threaten the survival of the species. A trade export permit will only be granted when certain conditions have been met. NOAA Fisheries is responsible for the majority of marine species that are listed under CITES. Species covered by CITES are listed in different appendices according to their conservation status. Beaked whales and baleen whales are both listed in Appendix I, which includes species threatened with extinction and provides the greatest level of protection, including a prohibition on commercial trade.

For More Information

- NOAA Fisheries role under the MMPA: https://www.fisheries.noaa.gov/topic/marine-mammal-protection
- Detailed website on Incidental Take Authorizations under the MMPA: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act
- ESA terminology: https://www.fisheries.noaa.gov/laws-and-policies/glossary-endangered-species-act
- Factsheet on BOEM's role in the offshore wind regulatory process: https://www.boem.gov/sites/default/files/documents/about-boem/Wind-Energy-Comm-Leasing-Process-FS-01242017Text-052121Branding.pdf
- International Whaling Commission: https://iwc.int/en/
- CITES: https://www.fisheries.noaa.gov/national/international-affairs/convention-international-trade-endangered-species-wild-fauna-and

What is "take"?

- "Take" is defined as "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" by the Marine Mammal Protection Act (MMPA; 16 U.S.C. §1362) and is prohibited for all marine mammals, unless specifically permitted or authorized.
- Similarly, "take" of protected species is prohibited under the Endangered Species Act (ESA) unless permitted, and is defined as "to harass, harm, pursue, hunt shoot, wound, kill, trap, capture, or

collect, or to attempt to engage in any such conduct" (50 CFR §17.3). "Take" in the wind energy development context typically refers to "incidental" take, i.e., take that is an unintentional consequence of lawful wind energy development activities, and is limited to harassment.

- "Harassment" is defined as any act of pursuit, torment, or annoyance which has the potential to injure or has the potential to disturb by causing disruption of behavioral patterns (16 U.S.C. §1362). The process of authorizing "incidental take" by federal agencies aims to limit harmful effects of human interactions with marine mammals (see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*). Authorizations only occur if take is determined to have negligible impacts on stocks or populations.

Detailed Answer

The Marine Mammal Protection Act (MMPA) prohibits "take" of marine mammals unless specifically permitted or authorized and lays out a system for allowable take in certain situations determined to have negligible impacts on stocks or populations (see *What federal and international environmental laws protect whales?*). "Take" is defined under the MMPA as to "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. §1362). Similarly, "take" is also prohibited under the Endangered Species Act (ESA) in the case of listed species unless permitted or exempt, and is defined as "to harass, harm, pursue, hunt shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (50 CFR § 17.3). Take does not necessarily mean that an animal is injured or killed. "Take" can be lethal or nonlethal and can be intentional (e.g., subsistence hunting, tagging during research activities) or "incidental" (e.g., unintentionally occurring as a result of some other lawful activity, such as vessel collision, fisheries bycatch, sound-related disturbance resulting from military exercises, etc.). Incidental takes are defined as unintended (but not unexpected) takes[109] and may be authorized if the federal agency finds that:

- Takes of individuals from a species or stock are small in number;
- Impacts on a species or stock are negligible; and
- The authorized take will not have an adverse impact on the availability of a species or stock for subsistence uses (and/or mitigation measures are required to increase the availability of marine mammals for subsistence needs).

In addition to these findings, any issued authorization must prescribe (1) permissible methods by which incidental take will occur, (2) mitigation measures to avoid/minimize take (e.g., means of having the least practicable adverse impact on the affected species or stock and their habitat), and (3) requirements for monitoring and reporting. Incidental Take Statements (ITAs) are issued following agency consultations and are only granted if the activity is not likely to adversely affect the species or critical habitat, or if there are expected to be adverse effects, that the activity would not jeopardize the species or critical habitat. The MMPA further delineates the different levels of take on marine mammals:[110]

1. Level B Harassment – Has the potential to disturb a marine mammal or stock causing disruption of behavior patterns but does not have the potential for injury and includes behavioral disturbance and temporary hearing threshold shifts.
2. Level A Harassment – Has the potential to injure a marine mammal or stock in the wild, which includes auditory injury and other non-serious injuries.
3. Mortality and serious injury.

[109] Incidental Take Authorizations: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act

[110] Marine Mammal Protection Act Glossary: https://www.fisheries.noaa.gov/laws-policies/glossary-marine-mammal-protection-act

No lethal takes of whales have been authorized for offshore wind energy development; incidental take authorizations and statements to date have only been issued for incidental harassment (see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*). Incidental take is authorized by NOAA Fisheries[111] either through a formal rulemaking and Letter of Authorization (LOA) or an Incidental Harassment Authorization (IHA). An LOA authorizes take for up to 5 years, while an IHA authorizes take (limited to Level A or B harassment) for up to 1 year (16 U.S.C § 1373; Table 5). An LOA can authorize mortalities and serious injuries, while an IHA cannot (though, as noted above, these are not anticipated and have not been authorized to date under an LOA for offshore wind-related activities). Incidental Take Statements for endangered and threatened marine mammals through the ESA are only issued if such taking has been authorized under the MMPA.

Table 5. Types of authorizations required for different types of take under the Marine Mammal Protection Act based on type of take and length of time of activity.

Action consequences	Type of Authorization	Effective For
Level A or B Harassment only	Incidental Harassment Authorization (IHA)	Up to 1 year
Level A or B Harassment only	Letter of Authorization (LOA)	Up to 5 years
Serious injury or mortality	Letter of Authorization (LOA; not issued to date for offshore wind activities)	Up to 5 years

What kinds of marine mammal harassment from offshore wind development can be authorized under the Marine Mammal Protection Act (MMPA)?

- Under the Marine Mammal Protection Act (MMPA), marine mammal harassment (a form of incidental "take") is categorized as either Level A or Level B harassment. Level A harassment is defined as an act that may non-lethally injure a marine mammal (e.g., permanent hearing damage). Level B harassment is defined as an act that may disrupt marine mammal behavior, which also includes temporary changes to hearing (see *What is take?*).
- Incidental takes may only be authorized when the number of affected individuals is small, and potential impacts are expected to be negligible (i.e., not expected to adversely affect the species or stock through effects on annual recruitment or survival).
- For offshore wind development activities, NOAA Fisheries has not authorized any lethal take of marine mammals but has authorized both Level A and B harassment for construction activities and Level B harassment for site characterization activities.

Detailed Answer

Upon request, the MMPA and its implementing regulations allow incidental "take" [112] of small numbers of marine mammals by entities (e.g., individuals, organizations, businesses, etc.) who engage in a specified lawful activity in a specified geographic region (16 U.S.C. § 1361-1407; see *What federal and international environmental laws protect whales?*). Incidental take is an unintentional, but not unexpected, take (see *What is "take"?*). Harassment is a critical component of the broader concept of incidental take, which acknowledges that lawful human activities can negatively impact marine mammals, even if an activity does not cause overt physical harm or mortality. In general, for harassment to be authorized under the MMPA, the specified activity must only affect small numbers of individual animals, and the effects of the taking must be "negligible." Mitigation measures are also required (i.e., the "means of effecting the least

[111] Incidental take is authorized by the U.S. Fish and Wildlife Service for polar bears, manatees, sea otters, and walrus; it is issued by NOAA for all other marine mammals.
[112] "Take" is defined in the MMPA as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal"

practicable adverse impact").[113] Marine mammal harassment is categorized by the statute into two levels: Level A and Level B harassment. The two-tier classification system was implemented with the 1994 amendments to the MMPA to clarify what specific effects constitute harassment.[114] Marine mammal harassment is non-lethal.

Level A harassment involves actions that can potentially injure a marine mammal or stock in the wild. It includes non-lethal harm from direct interaction with animals or permanent acoustic injury, like activities causing permanent hearing damage (i.e., partial loss of hearing at specific frequency bands, also called permanent threshold shifts) due to loud underwater noises (see *What are the effects of anthropogenic sound on marine mammals?*). By comparison, Level B harassment is less severe but still disruptive. This category includes actions that may disturb a marine mammal by disrupting behavior, which may lead to stress or displacement from critical habitats. This includes, but is not limited to, temporary loss of hearing (i.e., temporary threshold shifts) and altering behaviors such as: communication, navigation, respiration, nursing, breeding, feeding, or resting. Incidental take authorizations may be issued for specific actions determined likely to cause marine mammal harassment. Incidental Harassment Authorizations last up to one year (Level A and Level B harassment only), and Letters of Authorization last up to five years (Level A and B harassment; the latter may also be used to authorize mortality and serious injury, though none has been authorized in association with wind energy development; see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?).* Both authorizations require mitigation measures be implemented to minimize impact on marine mammals (see *What mitigation measures are required by regulators in the U.S. for offshore wind?)* and require monitoring and reporting related to expected take.

NOAA authorizes Level A and Level B harassment for a range of anthropogenic activities, mostly associated with the generation of underwater sound (e.g., military sonar and training exercises, oil and gas development, and marine construction projects). NOAA determines whether a sound source may cause Level A and/or Level B harassment based on scientifically defined thresholds of received sound levels and sound features (e.g., whether it is a continuous vs. intermittent sound, and impulsive vs. non-impulsive).[115] NOAA has authorized both Level A and B harassment for various offshore wind development projects, primarily related to the potential for acoustic impacts associated with pre-construction surveys and construction activities (e.g., turbine installation). Higher intensity acoustic activities include impact pile driving and pneumatic hammering to install wind farm infrastructure, which have the potential to take marine mammals by both Level A and Level B harassment. Offshore wind acoustic activities that only have the potential to disturb marine mammal behavior, or cause Level B harassment only, include vibratory pile driving and high-resolution geophysical site characterization surveys. Take by mortality or serious injury has not been authorized for any offshore wind development activity, and Level A harassment has not been authorized for endangered North Atlantic right whales. Active authorizations for MMPA harassment and previous authorizations with associated monitoring reports can be accessed online through NOAA Fisheries.[116]

[113] NOAA Fisheries: Incidental Take under the MMPA

[114] MMPA Terms: https://www.fisheries.noaa.gov/national/laws-and-policies/glossary-permits-protected-resources#marine-mammal-protection-act-terms

[115] MMPA Acoustic Thresholds (2024): https://www.fisheries.noaa.gov/s3/2024-10/MM-Acoustic-Thresholds-OCT2024-508-secure-OPR1.pdf

[116] Current and Past Incidental Take Authorizations: https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable%23expired-authorizations

For More Information

- NOAA Fisheries Frequent Questions: https://www.fisheries.noaa.gov/marine-life-distress/frequent-questions-feeding-or-harassing-marine-mammals-wild
- NOAA Fisheries Laws & Policies - About MMPA: https://www.fisheries.noaa.gov/topic/laws-policies/marine-mammal-protection-act
- NOAA Fisheries – IHA Authorization Process: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act
- NOAA Fisheries – IHAs for Renewable Energy: https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable

What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?

- There are a range of mitigation approaches that are used by the offshore wind industry and/or other industries in various regions to help avoid and minimize potential effects to marine mammals from sound and vessel collisions.
- Mitigations generally fall into three categories, approaches to (1) reduce the likelihood of marine mammal presence in an area when sound-generating activities occur, (2) reduce the sound that is emitted into the environment, or (3) mitigate risk of vessel strikes.

Broad Answer

Two of the main ways that marine mammals may be affected by offshore wind development is via (1) the generation of underwater sound, and (2) vessel interactions (See *What are the potential effects of offshore wind development on whales?*). The main sources of offshore wind-related sounds are generated primarily by geological and geophysical surveys (during site assessment of wind energy areas) and installation of wind turbine foundations (during construction). All vessels operating on the water also pose a potential risk of vessel collisions (See *What factors influence vessel strike risk for large whales?*). There are various mitigation approaches available, some of which are used by the offshore wind industry and/or other industries in various regions to help avoid and minimize these potential effects (Table 6). The effectiveness of mitigation measures depends on many factors including species, specifications/implementation, and compliance. The mitigation plan for each offshore wind project is informed by the species likely to be found in the area, the geographic and environmental features of the area (such as seabed sediment type, which can influence options for turbine foundations), and the cost of the mitigation measure (Schoeman et al. 2020), and is defined by federal agencies (Bureau of Ocean Energy Management [BOEM], NOAA Fisheries), with additional approval by the International Maritime Organization required for vessel-related mitigation. Increasing our environmental, biological, and technical knowledge can lead to better decision-making and implementation of various mitigation techniques.

Table 6. Mitigation options to reduce potential effects to marine mammals from offshore wind development. Defined based on category (e.g., reducing sound impacts or vessel impacts), mitigation type (mitigation), location where mitigation has been implemented (Loc.), taxonomic focus (focus) and details of the mitigation approach.

Category	Mitigation	Loc.	Focus	Details
Reducing sound impacts	Temporal and spatial restrictions	U.S.	Cetaceans	Reducing or restricting activities that could cause impacts during locations or periods of the year with high presence of certain marine mammal species (i.e., during foraging or migration, feeding or social behavior), or during periods when mitigation monitoring for marine mammals may be difficult to do effectively (e.g., darkness or poor visibility).

Category	Mitigation	Loc.	Focus	Details
Reducing sound impacts	Mitigation monitoring	U.S. Europe	All	Monitoring established zones around sound-generating activities and delaying or stopping activities if marine mammals are present. Monitoring can occur visually via protected species observers (PSOs), acoustically via passive acoustic monitoring (PAM), and/or using advanced technology such as infrared imagery and possibly RADAR. Sound propagation modeling is used to inform size of clearance zones and understand potential impacts.
Reducing Sound Impacts	Ramp up/Soft-start	U.S. Europe	All	Methods that can be used to provide marine mammals the opportunity to move away from the area prior to sound generating activities include ramp-up/soft-start (where there is a gradual increase of sound intensity prior to full operations).
Reducing Sound Impacts	Acoustic deterrents[1]	Europe	All	Acoustic deterrents emit a particular sound to encourage individuals to move away from the area where other sound-generating activities may occur (not currently permitted under the Marine Mammal Protection Act).
Reducing sound impacts	Alternatives to impact pile driving	Europe	All	Alternative turbine installation methods that may be used instead of traditional impact pile driving with a hammer, including vibratory pile driving that uses movement and vibration or blue hammer technology which uses the weight of water. Many factors influence the feasibility, practicability and efficacy of alternatives.
Reducing sound impacts	Alternative foundation types	Europe	All	While most turbines to date have been installed using monopiles, other options such as gravity-based foundations (in which much wider foundations are placed on the seabed), suction buckets, and floating foundations are quieter to install. However, many factors influence the feasibility and practicability of these alternatives.
Reducing Sound Impacts	Sound abatement systems	Europe U.S.	All	To reduce the amount of sound emitted into the marine environment during pile driving of turbine foundations, there are multiple technologies available, including bubble curtains, casings, and resonators that absorb or block some of the sound emanating from the source.
Reducing Vessel Impacts	Reducing vessel activities	Global	Large whales	Reducing the likelihood of interactions between vessels and marine mammals can be achieved by identifying areas of high collision risk and rerouting vessel traffic or implementing vessel exclusion.
Reducing Vessel Impacts	Vessel Speed Restrictions	Global	Large whales	Limiting the speed at which vessels can travel can provide animals and vessel crew with more time to detect and avoid each other and can reduce the severity of injury if a collision occurs.
Reducing Vessel Impacts	Animal Observation on Vessels	U.S.	Large whales	Collisions with marine mammals may be avoided if individuals are detected and appropriate avoidance measures are implemented by the vessel operator. Trained observers or other technologies for mitigation monitoring (e.g., PAM; above) can be used. Reporting and sharing observations with other vessels aids in situational awareness and implementation of avoidance measures.

Detailed Answer

One of the main ways that marine mammals may be affected by offshore wind development is via the generation of underwater sound (see *What are the potential effects of offshore wind development on whales?*). The main sources of offshore wind-related sounds are generated primarily by geological and geophysical surveys (during site assessment of wind energy development areas) and installation of wind turbine foundations (during construction). Approaches to mitigate, or minimize the impact of, this sound currently fall into two main categories:

1) Reducing the likelihood of marine mammal presence in the area during the activity period, generally using: (a) time of year and geographic restrictions to conduct sound-generating activities when marine mammals are less abundant in the area; (b) monitoring areas around the sound-generating activity and halting or minimizing efforts when animals are present; (c) limiting sound-generating activities during periods when monitoring for marine mammal presence is difficult or ineffective; and (d) using ramp-up/soft-start that gives animals the opportunity to move away from the area before sound levels reach full intensity.
2) Reducing the amount of sound emitted into the environment, which is achieved via two fundamentally different sound reduction approaches: (a) reducing the amount of sound generated, and (b) reducing the radiation of sound by placing sound barriers at some distance from the source (Koschinski & Lüdemann 2020).

Marine vessels also pose a potential risk of vessel collisions with some types of marine mammals, especially large whales (see *What factors influence vessel strike risk for large whales?*). This risk is well-known in relation to the shipping industry; collisions are much more likely to occur and much more likely to kill whales when the ships are large and moving at high speeds (Vanderlaan & Taggart 2007, Currie et al. 2017). While not a risk specific to offshore wind energy development, operating vessels on the water introduces collision risk for marine mammals. The primary mitigation approaches to reduce the risk of vessel strike include: (1) reducing vessel activity in locations and/or time periods of higher risk; (2) vessel speed restrictions, which can be targeted by location, time period, vessel size, or other factors; and (3) using dedicated observation methods to assess whether animals are present near a vessel, and slowing vessel speed/changing course when a whale is detected.

The above mitigation measures are discussed in further detail below. Multiple mitigation measures are typically applied during offshore wind energy development. The effectiveness of mitigation measures depends on many factors including species, mitigation design, wind farm design, and the level of compliance. Selection of mitigation measures that are most likely to be effective for a given offshore wind project or situation requires a multi-species approach and active interactions between relevant stakeholders so that individual priorities can be identified and addressed (Redfern et al. 2019). The mitigation plan for each offshore wind project is informed by the species expected to be present, project-specific information, such as planned foundation type, the geographic and environmental features of the area (which can influence the type of foundations that are feasible, among other factors), and the costs of the mitigation measure (Schoeman et al. 2020).

Reducing Marine Mammal Exposure to Sound-generating Activities

Temporal and Spatial Restrictions

In some locations, marine mammal research efforts have identified areas of ecological importance based on the presence of endangered species, high marine mammal and/or marine biodiversity, or predictable aggregations of marine mammals exhibiting feeding, breeding, mating, or migrating behaviors (Bailey & Thompson 2009, Sveegaard et al. 2011). Sound-generating activities can be avoided at locations and/or times of the year when aggregations are known to occur (Compton et al. 2008). The extent and duration of these aggregations may change over time, and so it is the responsibility of government agencies and research institutions to continue monitoring to identify effective spatial and temporal resolution of these types of restrictions (Compton et al. 2008). In addition to restricting activities during particular times of year, restricting activities to certain times of day may also ensure that sound-generating activities are only occurring during periods of adequate monitoring of marine mammal presence (see mitigation monitoring below).

Mitigation Monitoring

Monitoring for the presence of marine mammals within defined zones around sound-generating activities is conducted, such that additional action can be taken as needed (Verfuss et al. 2018). The size of the zones varies by geography and likely species presence, depends on the type of sound-generating activity (e.g., length and timing of activity, sound level and frequency range) and is informed by sound propagation modeling (Faulkner et al. 2018) and NOAA acoustic guidance (NMFS 2018). Monitoring occurs prior to and during activities to ensure the zone remains clear of marine mammals to minimize likelihood of exposure to deleterious levels of sound. Detection of marine mammals within this zone may lead to delays in the start of activities or shut down activities after they have commenced (Joint Nature Conservation Committee 2017). These zones can be monitored in multiple ways:

1. **Visual Monitoring using Protected Species Observers (PSOs)** – Trained marine mammal observers (known as PSOs in the U.S.) act as independent data collectors and scan the sea surface to monitor the presence and behavior of marine mammals within the defined zone of influence for activities, such as naval exercises, seismic surveys for offshore oil and gas development, and underwater construction and demolition (Baker et al. 2013; see *What are Protected Species Observers and what data do they collect about marine mammals?*). The standard procedure is for each observer to keep watch from a suitable location, which allows a clear 360-degree view of the sea surface, beginning no less than 30 min prior to activity commencement. The number of observers used varies between countries and circumstances, including the type of sound-generating activity and the size of the zone being monitored. The range at which observers can detect animals varies by species, viewing altitude, weather conditions, and other factors. Visual detection range should be considered when designing the mitigation monitoring plan. Effective visual detection range should be measured at the start of the activity, and the monitoring protocols should be adjusted, if necessary. An animal must surface within the PSO's visual range in order to be detected; as such, the proportion of time different species spend below the surface influences their detectability. For larger zones, observers can also be deployed from additional vessels or aircraft to facilitate monitoring of a larger area, typically prior to commencement of a sound-generating activity but often during the activity as well. If a marine mammal is detected in the defined zone, it is the responsibility of the PSO to advise the crew what mitigation is necessary (Compton et al. 2008).
2. **Passive Acoustic Monitoring (PAM)** – This approach detects animal vocalizations using underwater microphones (hydrophones). While hydrophones are used in various research and monitoring scenarios, mitigation applications require real- or near real-time detections, rather than archiving sound data for later review. This involves a combination of artificial intelligence algorithms to identify possible mammal sounds and biologists who review these data and make decisions about when a mitigation action such as shutdown of pile driving is necessary (Kowarski et al. 2020). PAM systems can be deployed from stationary platforms, such as moored buoys, or on autonomous vessels, such as ocean gliders (Baumgartner et al. 2020), or can be towed behind crewed or uncrewed platforms. Detection of marine mammals varies greatly with species (for example, the calls of large whales are generally audible at much larger distances than those of dolphins), water depth and salinity, and other factors, but is often in the range of tens of

kilometers (Ahonen et al. 2021, Johnson et al. 2022). However, detection of animals via PAM requires those animals to vocalize, and vocalization patterns can vary substantially between species, individuals, behavior, and life history stages, among other factors. As such, visual monitoring and PAM are often paired to help maximize the chance of detecting animals if they are present.

3. **Active Acoustic Monitoring** – This involves sending pulses of sound into the water and receiving back acoustic reflections from animals present in the water column. Fish finders, often used by fishermen, are one type of active acoustics. Sonar target strength is a key determinant of the likelihood of detection, which correlates with body size of the target (Verfuss et al. 2018). The detection range of these systems is dependent on multiple factors including frequency, source level, beam shape, and waveform, but generally ranges from 50 m–2 km, or 164 ft–1.2 mi (Verfuss et al. 2018). Some active acoustics are within the hearing range of some marine mammals, so the method must be considered with caution and may not be a permittable form of monitoring under the Marine Mammal Protection Act (Stein & Edson 2016).
4. **Thermal Infrared Technology** – An electro-optical imaging sensor (e.g., thermal camera) can detect temperature differences between the body of a warm-blooded marine mammal (or its blow, when whales come to the surface to breathe) and that of the surrounding environment (Smith et al. 2020). As with all of these technologies, it is more reliable at detecting animals at closer distances, but, in tests with humpback whales, appears to be reliable at distances of up to several kilometers (Zitterbart et al. 2020).
5. **RADAR** – Radio detection and ranging emits radio microwaves into the air and echoes from the animal are picked up by an array of receivers to determine the range and direction of the animal. While not currently widely used in this context, RADAR can detect marine mammals at the surface from the exposed body of the animal, an exhalation, or from disturbance on the sea surface, and therefore is most effective at detecting larger animals in calm conditions (Verfuss et al. 2018). The ability of RADAR systems to discern marine mammals from clutter at the surface improves with increased bandwidth, power transmission (range), and scan rate. Empirical data are lacking on the detection abilities of specialized systems, but there is some evidence that marine RADAR range in optimal sea state conditions is <1 km, or 0.6 mi (with higher likelihood of detection with larger-bodied species; Verfuss et al. 2018).

Visual monitoring has a number of problems besides human error, including that it is not reliable at night, can be compromised during the day due to adverse weather conditions (increased sea state, precipitation, fog), and many marine mammals spend a large portion of their time underwater, where they cannot be detected using this method. Combining visual monitoring with passive acoustics can help overcome some of these issues, as PAM can operate under most conditions (Verfuss et al. 2019). However, marine mammals, and particularly large whales, do not continuously vocalize, meaning that PAM also has its detection limitations. Active acoustics, thermal infrared, and radar technologies may also help with monitoring in poor visibility conditions (Verfuss et al. 2018, Smith et al. 2020). Thermal imaging has undergone substantial testing and research and development activities in recent years (e.g., Zitterbart et al. 2020, Smith et al. 2020). The efficacy of active acoustics and radar for monitoring zones is less well known, though the research on different mitigation measures is evolving rapidly.

Ramp up and Deterrents

The gradual increase of sound intensity prior to full operations, known as 'ramp-up' or 'soft-start,' aims to deter animals away from the site to minimize risk of auditory injury, acting as a warning for marine mammals in the vicinity to move away prior to full sound-level activities (Wensveen et al. 2017). The length of time this ramp-up occurs can range from 20–45 minutes (Compton et al. 2008, Joint Nature Conservation Committee 2017). This approach is used for sound-generating activities across industries, including naval sonar exercises, seismic surveys for oil and gas exploration, geophysical surveys, and pile driving during offshore construction, which vary in methods and sound characteristics (Wensveen et al. 2017; also see *What are the potential effects of offshore wind development on whales?*).

The type and extent of a marine mammal's response to these initial levels of sound will be affected by a variety of factors, including behavior, experience, motivation, and conditions (Bailey et al. 2014; see *What are the effects of anthropogenic sound on marine mammals?*). Much of what we know about potential responses comes from studies during seismic surveys for oil and gas development. A study of short-finned pilot whales observed an avoidance response away from the ramp-up of a 2-D seismic survey that began when they were 750 m (0.46 mi) away from the airgun array (Weir 2008). For migrating humpback whales exposed to ramp-up during seismic surveys, most groups moved away from the source, but the use of ramp-up did not increase the strength of response (e.g., whales moved away similarly for ramp up and higher sound levels; Dunlop et al. 2016). While ramp-up is implemented as a 'common sense' approach, few studies have examined the effectiveness specific to offshore wind related activities, and there may be logistical limitations in the use of these techniques for pile driving of turbine foundations into the seabed, as the design of the hammer used for pile driving must be suitable for these methods.

While not currently permitted in the U.S., it may also be possible to deter animals away from sound sources to distances where the risk of sound-related effects is reduced to acceptable levels. Acoustic deterrent devices (ADDs), such as seal scarers or acoustic pingers, were originally developed to keep seals away from aquaculture and fishing gear and have been effective at deterring harbor porpoises from offshore wind-related activities in Europe (Dähne et al. 2017). These emit sound pulses for 15+ minutes prior to sound-generating activities to encourage animals to move away from the site. There are a variety of devices from various brands that have different acoustic characteristics (Sparling et al. 2015, McGarry et al. 2022). There is evidence that harbor porpoise are deterred to a minimum of 7.5 km, or about 4.7 mi (Brandt et al. 2013) and at least some whale species also appear to respond to ADDs (Boisseau et al. 2021). However, the level and duration of response to these types of devices are species-specific, and possibly individual-specific, as shown in a study on minke whales (McGarry et al. 2017), meaning their effectiveness is not guaranteed. These techniques also introduce additional sound into the environment, have the potential to cause impacts to hearing (either Temporary Threshold Shifts or Permanent Threshold Shifts; Todd et al. 2021; see *What are the effects of anthropogenic sound on marine mammals?*) and effectively are a type of intentional harassment of marine mammals, and they are not currently permitted for use in the United States under the Marine Mammal Protection Act.

Sound Reduction

Reducing Sound Production

Reduction in sound emissions can be achieved via low sound alternatives to pile driving for turbine foundation installation. Alternatives to traditional impact piling, which involves hitting the pile with a large hammer to drive it into the seabed, include vibratory piling and BLUE piling. Vibratory hammers work by vibrating the pile and causing a temporary reduction in soil resistance, so that the pile can sink into the seabed. Vibratory hammers can also be used to reduce the time needed for impact piling, and thereby reduce the duration of sound (Koschinski & Lüdemann 2013). BLUE Piling Technology, though not currently commercially available, uses the impact of a large water mass to slowly drive down piles over time, which takes longer but emits less sound and vibration than other methods and therefore may represent a future alternative (Verfuss et al. 2019).

There are also multiple types of foundations that can be installed without pile driving, including gravity-based foundations (in which much wider foundations are placed on the seabed), suction buckets, and floating foundations (Figure 16), all of which produce less sound during installation. However, there are technical and cost considerations that may preclude use of certain foundation types in certain seabed substrates and water depths.

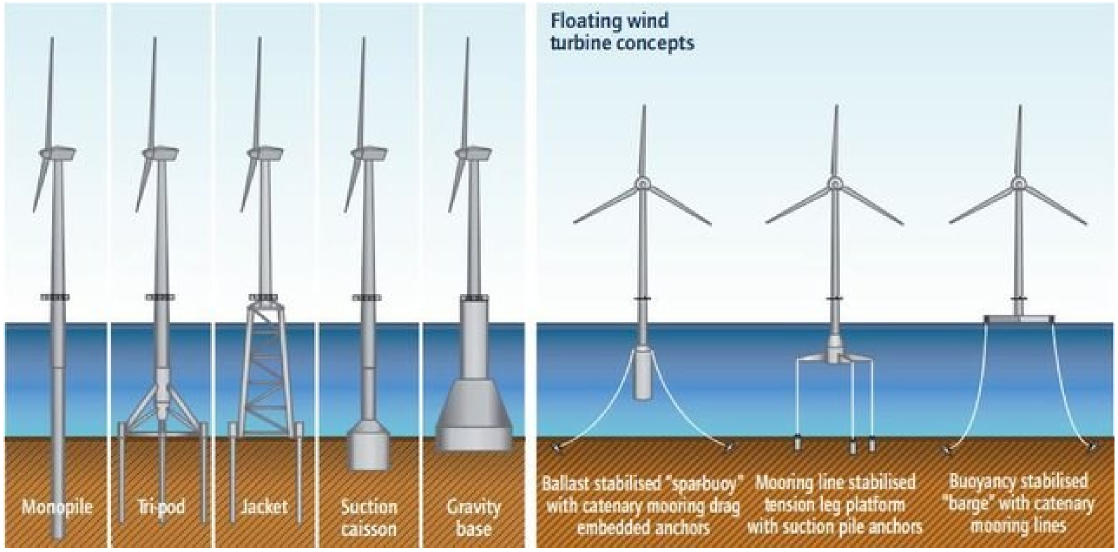

Figure 16. Fixed and floating turbine foundation designs. From Konstantinidis & Botsaris (2016; available via CC by 3.0).

Reducing Sound Propagation

There are multiple sound-dampening technologies that can be used to reduce the amount of sound energy that is released into the surrounding environment, particularly during turbine foundation installation. These sound abatement systems include bubble curtains, casings, and resonators (Figure 17). Bubble curtains and casings provide a sound barrier around the piling position that prevents sound at certain frequencies from spreading. Bubble curtains consist of a nozzle hose that releases air bubbles in a radius of tens to hundreds of meters, and the bubbles block a portion of the sound being emitted. Casings enclose the pile at close distance with double-walled steel casing or sound-absorbing foam (Verfuss et al. 2019). Resonator systems surround the foundation during pile driving with sound-absorbing or reflective material. Bubble curtains and casings have been used for mitigating sound during offshore wind construction in Europe (Verfuss et al. 2019) and bubble curtains are also being used in the U.S.[117] (casings are currently not commercially available for the size of turbine currently being installed in the U.S.). Implementation of bubble curtains at offshore wind farms during monopile installations has resulted in a 75–95% decrease in the sound-affected area for harbor porpoises (Nehls et al. 2016, Dähne et al. 2017). There are many factors that affect the efficacy of these technologies, however, including configuration, turbine diameter, deployment depth, and the frequencies of sound that are targeted for reduction (e.g., to better protect different marine mammal taxa with varying hearing capabilities), and often combined approached may provide the best sound attenuation (Bellmann et al. 2020). Verfuss et al. (2019) and Bellmann et al. 2020 provide in-depth description of the different technologies that have been used by the offshore wind industry or are promising for future application.

[117] Example use of bubble curtain: https://maritime-executive.com/article/vineyard-wind-tries-bubble-curtain-system-to-cut-pile driving-sound

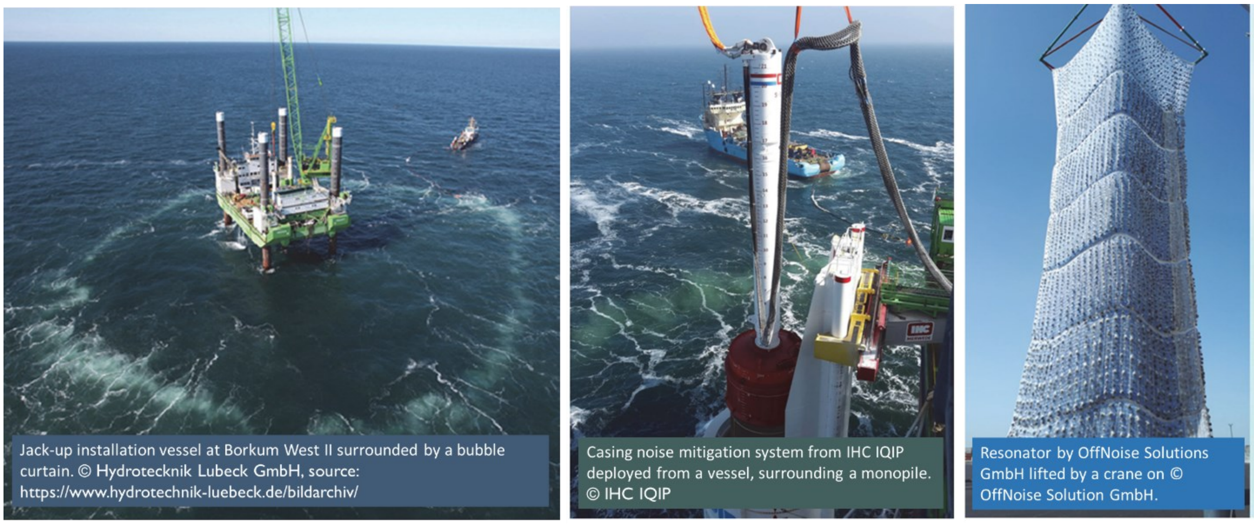

Figure 17. Examples of sound abatement systems including a bubble curtain (left), casting (middle), and resonator (right), figures adapted from Verfuss et al. 2019.

Vessel Strike Mitigation

Reducing Vessel Activity

If areas of high collision risk are identified, it is possible that vessel traffic can be re-routed provided that these routes do not compromise safe marine navigation (Schoeman et al. 2020). This approach has been successfully implemented to protect North Atlantic right whales in Boston Harbor and the Bay of Fundy, for example (Vanderlaan et al. 2008, Van Der Hoop et al. 2015). [118] In addition to re-routing, this type of approach may also include the establishment of vessel traffic exclusion zones to reduce the number of vessels in an area. As with temporal and spatial sound restrictions described above, this requires an understanding of the spatiotemporal distributions of marine mammals. Rerouting vessel traffic around areas with known concentrations of whales is an effective mitigation measure (Vanderlaan et al. 2008, Van Der Hoop et al. 2015). While mitigation requirements specific to the offshore wind industry in the U.S. are under the regulatory control of BOEM and NOAA Fisheries, involvement and approval by the International Maritime Organization[119] would be needed in cases related to changes in vessel routes and exclusion zones.

Vessel Speed Restrictions

Vessel speed restrictions have been implemented in multiple industries and locations to provide animals and vessel crew with more time to detect and avoid each other as well as to reduce the severity of injury (Schoeman et al. 2020). Higher speed and larger vessels pose greater risk as collisions result in more serious injuries due to the higher force of impact (e.g., blunt force trauma) and the probability of deeper and more lethal lacerations from vessel bows and propellers (e.g., sharp force trauma; Wang et al. 2007, Schoeman et al. 2020), though the relationship between speed and severity of injury is species-dependent (Kite-Powell et al. 2007, Vanderlaan & Taggart 2007, Schoeman et al. 2020; see *What factors influence vessel strike risk for large whales?*). However, recent analyses and documented interactions between large whales and vessels suggest that smaller vessels operating at high speeds may cause lethal injury as well (Stepanuk et al. 2021, NOAA 2022b). In addition to a higher probability of lethal injury, high vessel speeds result in a decreased probability of detection of marine mammals by vessel operators,

[118] More information: https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales#vessel-routing
[119] IMO Ship Routing Information: https://www.imo.org/en/OurWork/Safety/Pages/ShipsRouteing.aspx

which in turn can result in higher probability of collision (Gende et al. 2011). In 2008, a vessel speed restriction rule was implemented by NOAA to specifically protect North Atlantic right whales, and states that all vessels 65 ft or longer must travel at 10 nautical miles per hour (knots) or less in certain locations along the U.S. Atlantic coast, and at certain times of year, as designated by NOAA; these locations are termed seasonal management areas (SMAs).[120] SMAs aim to cover high-risk areas where right whales consistently occur, including migratory routes and calving grounds. In addition to mandatory SMAs, voluntary dynamic management areas (DMAs) are also designated; mariners are encouraged to avoid these areas if possible, or to reduce speeds to 10 knots or less while transiting through these areas.

Despite the implementation of this rule, vessel collisions with North Atlantic right whales have continued to occur (Garrison et al. 2022), linked to climate change-driven shifts in right whale distribution (Meyer-Gutbrod et al. 2021); see *How is climate change affecting large whales?*). This led NOAA Fisheries in 2022 to announce proposed changes to the North Atlantic right whale vessel speed rule to further reduce the likelihood of vessel collisions (NOAA 2022b). These changes, if adopted, will expand the spatial boundaries and timing of seasonal speed restriction areas in the U.S. Atlantic and also expand mandatory speed restrictions of 10 knots or less to include most vessels 35–65 feet in length. Additional information on right whales and vessel strikes, including vessel speed rules, are available on the NOAA Fisheries website.[121] It is important to note that while the vessel speed rule confers vessel slow down benefits to other large whale species, it is tailored to North Atlantic right whales and gaps in protection for other east coast whale species remain.

Animal Observation

Collisions with marine mammals may be avoided if individuals are detected and appropriate avoidance measures are implemented by the vessel operator. Vessel crew are generally not trained to detect and identify marine animals and are likely focused on other aspects of the voyage; thus, placing a trained, dedicated observer onboard a vessel (such as a Protected Species Observer or dedicated, well-trained crew member observer) has been suggested to help increase the detection rate of whales along a vessel's route during day-light hours (Schoeman et al. 2020). Some of the technologies described above related to monitoring mitigation zones (e.g., infrared cameras, active sonar) could be used to augment visual observations for this purpose. In addition, reporting observations in the United States is mandatory for protected species. Reporting aids in management decisions related to vessel speed restrictions (see above) and adds to situational awareness of all vessels in the region to avoid potential interactions with marine mammals.

What marine mammal mitigation measures are required by regulators in the U.S. for offshore wind?

- The details of requirements for specific offshore wind projects varies based on permit requirements from the Bureau of Ocean Energy Management (BOEM) and can be found in various permitting documents including the Construction and Operations Plan Approval[122] and

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[120] Seasonal Management Areas: https://www.fisheries.noaa.gov/resource/map/north-atlantic-right-whale-seasonal-management-areas-sma

[121] Proposed modification to vessel speed rule: https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales#proposed-modifications-to-right-whale-speed-rule

[122] Example Construction and Operations Plan Approval for Vineyard Wind 1: https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/VW1-COP-Project-Easement-Approval-Letter_0.pdf

the Record of Decision.[123] In general, these requirements relate to reducing collision risk from vessels and impacts from sound during construction.

- To reduce vessel-related impacts, requirements generally include vessel speed restrictions (10 knots or less during certain periods of the year) and dedicated observers on vessels (when traveling above 10 knots).
- Generally, requirements related to reducing sound-related impacts during construction activities include temporal restrictions on pile-driving activities, mitigation measures during pile driving (e.g., Protected Species Observers and passive acoustic monitoring), ramp-up/soft start during sound-generating activities, and use of sound abatement systems (e.g., bubble curtains) during pile driving.
- Offshore wind mitigation and monitoring requirements are much more stringent than those for other maritime industries, such as shipping.

Detailed Answer

Mitigation for marine mammals at offshore wind facilities is determined on a site-by-site basis through various permitting processes. BOEM, for example, identifies conditions associated with approval of offshore wind farm Construction and Operations Plans (COPs) and these conditions include a range of mitigation measures. Additional information may also be available in the Record of Decision (ROD). NOAA Fisheries also includes required mitigation measures in their Biological Opinions for offshore wind projects (for species listed under the U.S. Endangered Species Act) and incidental take authorizations which authorize the taking of marine mammals, such as by behavioral disturbance, incidental to conducting certain activities for certain specified numbers of marine mammals under the U.S. Marine Mammal Protection Act (MMPA; see *What federal and international environmental laws protect whales?*; *What is take?*). The specific mitigation requirements for each offshore wind project are based on multiple factors, including geography and local/regional abundance/occurrence of species, as well as characteristics of the pile installation (e.g., number, size, timing, use of sound attenuation devices; BOEM 2021, 2022, 2023). However, there are types of marine mammal mitigation requirements that apply to all offshore wind facilities, including mitigation measures related to reducing collision risk from vessels and reducing sound emitted during construction activities. Many of the mitigation measures described in *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?* are required of offshore wind developers. To reduce vessel-related impacts, requirements include vessel speed restrictions at times of year when North Atlantic right whales may be most at risk, as well as dedicated Protected Species Observers on vessels (see *What are Protected Species Observers and what data do they collect about marine mammals?*). Mitigation requirements for reducing sound-related impacts include temporal restrictions on pile-driving activities, mitigation measures via Protected Species Observers and passive acoustic monitoring during pile-driving, ramp-up/soft start during sound-generating activities, and use of noise abatement systems during pile-driving activities.

Reducing Vessel-related Impacts

Vessel Speed Restrictions

All offshore wind project vessels, regardless of size, must travel at 10 nautical miles per hour (knots) or less when transiting to, from, or within the project area (with some geographic exceptions) during certain periods of the year when North Atlantic right whales are consider to be most at risk (generally Nov-April/May, but exact dates vary; BOEM 2021, 2022, 2023), with a few exceptions if allowed by permits (see below). In addition to these time windows, project vessels must also travel at a speed of 10 knots or less in Seasonal Management Areas (SMAs) and Dynamic Management Areas (DMAs) when they are in

[123] Example Record of Decision for Vineyard Wind 1: https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Final-Record-of-Decision-Vineyard-Wind-1.pdf

place. The SMAs and DMAs are areas identified by NOAA as part of the implementation of broader vessel speed regulations designed to protect North Atlantic right whales. These rules currently apply to all vessels 65 feet or longer, regardless of vessel type (50 CFR § 224). SMAs aim to cover high-risk areas where North Atlantic right whales consistently occur, including migratory routes and calving grounds. In addition, DMAs are designated when right whales are observed outside of the geographic extent or effective period of SMAs, and specifically when reliable sightings are obtained of three or more right whales within a 75 square nautical mile area (Silber et al. 2012). The size of a DMA is commensurate to the number of whales present and is put in place for 15 days. While vessel speed restrictions in DMAs are voluntary for other industries, they are required for offshore wind development-related vessels.

Recently, NOAA also approved the use of near real-time passive acoustic detections of North Atlantic right whales to designate additional vessel speed reduction areas (North Atlantic Right Whale Recovery Plan Northeast U.S. Implementation Team,[124] Murray et al. 2022). Combined, visually triggered DMAs and acoustically triggered areas are termed "Slow Zones". Increased vigilance and vessel speed reduction to 10 knots is either encouraged or required (varies by project). Technologies such as WhaleAlert[125] help provide near real-time information on sightings of marine mammals and the location of DMAs and slow zones.

Some projects have exceptions to vessel speed restrictions that are specific to crew transfer vessels, which are vessels that bring operations and maintenance personnel from shore to the offshore wind farm to conduct maintenance activities (BOEM 2021). These exceptions to vessel speed restrictions are only granted with a North Atlantic Right Whale Strike Management plan that has been approved by BOEM and NOAA Fisheries. These plans vary but may require additional observers on vessels to scan for marine mammals in the vicinity, as well as real-time passive acoustic monitoring to detect animals that may be present. If a North Atlantic right whale is observed within or approaching the transit route, vessels must travel 10 knots or less until clearance of the route for one to multiple days (exact timing varies by project).

Dedicated Observers on Vessels and Strike Mitigation

It is also required that offshore wind vessel operators and crew members maintain a vigilant watch for marine mammals and reduce vessel speed, alter course, and stop, if necessary, to avoid striking a marine mammal. The distance at which these strike mitigation measures are implemented varies by marine mammal species/group. Crew members must be trained in identification, strike avoidance techniques, and reporting of all marine mammals (including live, entangled, and dead individuals) to designated vessel contacts, who in turn handle reporting requirements detailed below. In addition, all project-related vessels traveling at speeds higher than 10 knots must have a dedicated visual observer on duty at all times to monitor a strike avoidance zone around the vessel. Visual observers may be professional Protected Species Observers (PSOs) who conduct these types of observations for a range of industries, or they may be crew members (see *What are Protected Species Observers and what data do they collect about marine mammals?*). Regardless, they must be adequately trained in identification and reporting (see below). As part of strike mitigation protocol, at times when vessel speed restrictions (above) are not applicable, vessel operators must reduce vessel speeds to 10 knots or less when "mother/calf pairs, pods, or large assemblages of cetaceans" are observed within the path of the vessel (BOEM 2021). In addition, vessels must maintain certain distances from marine mammals (50–500 m, depending on the species) and implement strike avoidance if animals approach or are detected closer than these distances. There are

[124] North Atlantic Right Whale Recovery Plan Northeast U.S. Implementation Team: https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/north-atlantic-right-whale-recovery-plan-northeast-us-implementation-team

[125] Whale Alert App: https://www.fisheries.noaa.gov/resource/tool-app/whale-alert

also requirements related to communication and reporting of sightings, whereby observations of listed species (under the Endangered Species Act) must be communicated in near real-time across project vessels that are operating concurrently, and North Atlantic right whale sightings must be immediately reported to federal agencies (BOEM, NOAA). All stranded, entangled, dead, or injured marine mammals that are detected during observations (regardless of whether the death/injury was related to project activities), and any vessel strikes caused by project vessels, or death or non-auditory injury caused by project activities must also be reported to federal agencies immediately (BOEM 2022a; see *What federal and international environmental laws protect whales?* *What is take?*.

Reducing Sound Impacts During Construction

Temporal and Spatial Restrictions

There are required time-area restrictions for pile driving of turbine and substation foundations to avoid generating large amounts of underwater sound during key periods when North Atlantic right whales are expected to be present. No pile driving can occur during certain months of the year (varies by location, but generally Dec/Jan-April) when North Atlantic right whales are predicted to be most likely to be in or near the construction area. There also may be time-of-day restrictions whereby pile driving cannot commence until at least 1 hour after civil sunrise and 1.5 hours before civil sunset (to minimize the potential for pile driving to continue after civil sunset when visibility is impaired and zones cannot be effectively visually monitored). Time-of-day restrictions may only be relaxed upon approval of an Alternative Monitoring Plan by BOEM and NOAA Fisheries that demonstrates effective monitoring of marine mammals during nighttime conditions. For some projects, there are also restrictions related to the number of monopile foundations allowed to be installed per day (BOEM 2023). In addition, if a DMA or Slow Zone is designated in the vicinity of an active construction area, passive acoustic monitoring must be extended to the largest practicable detection zone for North Atlantic right whales (e.g., extending beyond the established clearance and shutdown zones if possible; BOEM 2022). This is required if a DMA or Slow Zone is within a certain distance of pile driving (between 3.2 and 4.1 km, depending on the type of turbine foundation and amount of sound generated when it is driven into the seabed), or if the DMA/Slow Zone overlaps with established clearance and shutdown zones around pile-driving activity (see below).

Mitigation Measures

Mitigation monitoring of various impact zones around pile-driving activities is required across projects and is detailed in each offshore wind facility's Foundation Installation Pile Driving Marine Mammal Monitoring Plan and Passive Acoustic Monitoring (PAM) Plans. These Plans include both visual monitoring via PSOs and PAM. PAM must demonstrate near-real-time capability of detections within a certain distance from the pile-driving location (5-10 km, varies by project; BOEM 2021, 2022, 2023). In general, there are monitoring, clearance, and shutdown zones that are visually and acoustically monitored for the presence of marine mammals (note the size of visual clearance and PAM clearance zones vary). Monitoring zones may be larger and are often defined by regulatory Level A and B harassment zones (estimated for each project based on acoustic modeling and NOAA-defined sound thresholds and approved by NOAA Fisheries; see *What is take?* for harassment definitions). For the monitoring zone, the presence of animals is recorded to estimate the number of animals that have been exposed to the activity, but pile driving is not necessarily required to stop if animals are detected in the monitoring zone (depending on the incidental take authorization; see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*). The clearance zone represents the area where animals cannot be present for 30-60 minutes prior to the commencement of pile driving and overlaps with the monitoring zone. Finally, the shutdown zone is the area within which stoppage of pile driving must occur (if safe to do so) with the detection of marine mammals (E-TWG Marine Mammal Specialist Committee 2020). The size of these three zones is defined by species group (see Table 7 as example). These zones are refined based on field measurements of sound generated during installation of certain piles. There are various requirements related to visual monitoring, including PSO qualifications, number of PSOs, vantage points, and other aspects. In addition, pile driving can only commence when the clearance zones are fully visible for at least 30–60 minutes, and there must be an Alternative Monitoring Plan in place (and approved by BOEM and NOAA Fisheries) for enhanced monitoring if poor visibility conditions unexpectedly arise or if pile driving must continue into the night. In areas with higher North Atlantic right whale activity, there may also be requirements for vessel-based and/or unmanned aerial surveys and additional passive acoustic monitoring to occur for a certain period of time prior to the start of pile-driving activities.

Table 7. Example of clearance and shutdown zones by species for the Southfork Project. The minimum visibility (representing the visibility conditions required for observations to occur, when visibility is reduced below this range due to ambient weather conditions, pile driving cannot occur) is 2,200 m. Sources: NOAA 2022, BOEM 2023.

Species	Type of Detection	Clearance Zone (m)	Shutdown Zone (m)
North Atlantic right whale	Passive acoustic monitoring	5,000	2,000
North Atlantic right whale	Visual	Any distance	Any distance
Fin, sei, humpback, minke, and sperm whales	Visual	2,200	2,000
Harbor porpoise	Visual	450	450
Dolphins, long-finned pilot whale	Visual	100	50
Gray and harbor seal	Visual	150	150

Ramp Up/Soft-start

All offshore wind energy projects in the United States to date are required to use soft-start procedures during pile driving (construction) and geological and geophysical surveys (site characterization). This is intended to “ramp up” the amount of underwater sound being generated, to allow marine mammals and other wildlife more time to leave the vicinity of the activity (see *What mitigation measures are available to avoid or minimize offshore wind effects on marine mammals?*). While the exact procedures vary, more recent requirements include a minimum of 20 minutes of 4–6 strikes per minute at 10–20 percent of the maximum hammer energy (BOEM 2023), before both the strike frequency and hammer energy can be raised to full strength. Soft starts are required for each new pile, as well as when pile-driving activities restart after >30 minutes of stoppage.

Sound Abatement Systems

Use of noise abatement systems are required for most offshore wind projects that have turbine and substation foundations comprised of monopiles or pin piles (e.g., individual legs of a jacket foundation; see *What are the major components of an offshore wind farm?* for description of foundation types). These systems are deployed during pile driving of turbine foundations to reduce the distance and duration that resulting sound travels through the water and minimize potential acoustic impacts to wildlife. The system proposed and used to date in the United Sates included a combination of a double bubble curtain with a near-field sound mitigation system based on Helmholtz resonator technology (BOEM 2021, 2022, 2023; for more information, see *What are the available mitigation measures to avoid or minimize offshore wind effects on marine mammals?*). In addition, all projects are required to develop and implement a Pile Driving Source Verification Plan that includes conducting field verification of sound attenuation during pile driving and requires the modification of the initial monitoring, clearance, and/or shutdown zones, if needed, based on the results. As the first commercial-scale offshore wind farms in the U.S. Atlantic complete construction activities, sound verification data from these systems will become available to inform the use of noise abatement systems moving forward.

What marine mammal-related permits, approvals and authorizations do offshore wind developers get?

- The Bureau of Ocean Energy Management (BOEM) is responsible for permitting offshore renewable energy development in federal waters under the Outer Continental Shelf Renewable Energy Program (authorized by the Energy Policy Act of 2005). Offshore wind project federal permitting and authorizations relating to marine mammals are under the purview of BOEM, NOAA Fisheries, and the Bureau of Safety and Environmental Enforcement (BSEE).
- The permitting process includes separate approvals for site assessment activities, construction and operation activities, Endangered Species Act (ESA) consultations, and incidental take authorizations under the Marine Mammal Protection Act (MMPA). All of these approvals and/or consultations aim to assess the level of impact of project activities and identify required mitigation measures (including avoidance and minimization efforts).
- Incidental Take Authorizations (ITAs) granted by NOAA Fisheries under the MMPA and Incidental Take Statements granted under the ESA, are required for activities such as site assessment surveys and construction activities that could impact marine mammal species or stocks. Authorizations are only granted if the activities would:
    - MMPA: take "small numbers" of marine mammals and be likely to have no more than a "negligible impact" on the species or stock. In the authorization, the agency prescribes permissible methods of taking and other means (e.g., mitigation measures) of effecting the least practicable adverse impact on the affected species or stocks and their habitat.
    - ESA: either not be likely to adversely affect the species or critical habitat, or if there are expected to be adverse effects, that the activity would not jeopardize the species or critical habitat.

Detailed Answer

Under the Outer Continental Shelf Renewable Energy Program, authorized by the Energy Policy Act of 2005 (Public Law No: 109-58), the Bureau of Ocean Energy Management (BOEM) is responsible for permitting offshore renewable energy development in federal waters (which include ocean waters from 3-200 nautical miles from shore for U.S. Atlantic states). Under this Act, BOEM is responsible for ensuring that projects are developed in environmentally responsible ways and to consider other uses of the Outer Continental Shelf. BOEM is also required to coordinate with relevant federal agencies, as well as state and local governments. Within three miles of the shoreline, states control marine waters and have their own environmental permitting processes for marine industries. The development of offshore wind energy in the U.S. is thus guided by both federal and state permitting processes, which require years of data collection and stakeholder engagement with multiple opportunities for public comment. Permitting and authorizations relevant to marine mammals fall under the purview of BOEM and NOAA Fisheries[126] (Table 8), with a range of additional permits from other federal agencies for aspects not specific to marine mammals (e.g., U.S. Coast Guard approval for navigation lighting). Project components located within state boundaries (e.g., on land and within three nautical miles from shore) must also abide by state laws and regulations (but state law does not supersede federal authority under the Marine Mammal Protect Act [MMPA] and Endangered Species Act [ESA]). State authorizations and consultations are state-specific, but typically include permits related to transmission landing, coastal environmental impacts, and underwater cables in state waters.

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[126] The U.S. Fish and Wildlife Service, rather than NOAA Fisheries, is responsible for the protection of certain marine mammal species such as sea otters that are relevant to offshore wind energy development in some geographic regions (such as the U.S. Pacific).

The permitting process for an individual wind project begins once a lease has been obtained from BOEM and includes site assessment and construction and operations plans (SAP and COP, respectively). In addition to the SAP and COP process, developers must also apply for and receive incidental take authorizations from NOAA Fisheries under the MMPA for potential take resulting from activities during either of these phases that could impact marine mammals, and Section 7 consultations occur under the Endangered Species Act (ESA) for protected species and critical habitat (see *What is take?*). While not specific to marine mammals, the Facility and Design Report (FDR) and Fabrication and Installation Report (FIR) delineate any measures required as a result of these earlier consultations and must be submitted by the developer and approved by the Bureau of Safety and Environmental Enforcement (BSEE) before construction is allowed to commence.

Table 8. Permitting and consultation requirements for offshore wind developers that are specifically applicable to marine mammals. Modified from NYSERDA (https://www.nyserda.ny.gov/All-Programs/Offshore-Wind/Focus-Areas/Permitting).

Permitting/Consultation Requirement	Federal Regulatory Agency
Receive approval for a Site Assessment Plan (SAP)	BOEM
Receive approval for a Construction and Operations Plan (COP)	BOEM
Consultations under the Endangered Species Act. Resulting Biological Opinion includes an incidental take statement (ITS), when applicable	NOAA Fisheries
Apply for/receive an incidental take authorization (ITA) under the Marine Mammal Protection Act	NOAA Fisheries

The steps in this process relevant to marine mammals are detailed below (Figure 18). The National Environmental Policy Act (NEPA), MMPA, and ESA processes are all interdependent and require much of the same information for a particular project to ensure that both BOEM and NOAA Fisheries meet their regulatory requirements under these statues. As such, this process requires a high level of coordination among federal agencies and the offshore wind energy developer.

Site Assessment Plan (SAP)

Offshore wind developers may be required to submit a Site Assessment Plan to BOEM that provides a description of proposed site assessment data collection activities, including details related to the construction and installation of a meteorological tower on the site, as well as planned geophysical and geotechnical surveys of the ocean bottom, and any other 'site assessment activities', which are defined as "those initial activities conducted to assess an area on the Outer Continental Shelf, such as resource assessment surveys (e.g., meteorological and oceanographic) or technology testing, involving the installation of bottom-founded facilities" (30 CFR § 585.600(a)(1))[127]. BOEM reviews and approves, approves with conditions, or disapproves the SAP. As of April 2024, 20 offshore wind projects have received SAP approval.[128]

Construction and Operations Plan (COP)

The Construction and Operations Plan (COP) is a detailed plan for the construction and commercial operation of a wind energy project submitted to BOEM by the developer. The COP provides a description of all proposed activities and planned facilities (onshore and offshore) for the lease area. The COP includes data and results from survey investigations (including those conducted to support the SAP) and provides the analysis of direct and indirect environmental and socioeconomic impacts resulting from the offshore

[127] Note: Prior to the Renewable Energy Modernization Rule, passed in July 2024, SAPs were required for all commercial leases. Under previous regulations, a lessee could not progress to site assessment activities without an approved SAP. Now SAPs are only required for certain activities, as described.
[128]Northeast Ocean Data Portal: https://www.northeastoceandata.org/offshore-wind-projects/

wind farm project. The submission of the COP starts the NEPA process (detailed in Figure 15 in *What federal and international environmental laws protect whales?*), which includes publication of a Notice of Intent, the draft and final Environmental Impact Statements, and the Record of Decision (ROD), with public comment periods and input from consultations with NOAA Fisheries. Publication of the Record of Decision for the Construction and Operations Plan marks the end of the NEPA review process (see *What federal and international environmental laws protect whales?*). As of April 2024, eight proposed offshore wind projects in the U.S. have received COP approval.

Environmental Impact Assessment

The submission of the COP to BOEM initiates the Environmental Impact Assessment (EIA) process under NEPA (see *What federal and international environmental laws protect whales?*). BOEM develops the Environmental Impact Statement (EIS), a document containing detailed analysis of the project as proposed, as well as other alternative project designs/locations, with consideration of potential environmental impacts, as well as impacts on aesthetics, cultural resources, socioeconomics, and air and water quality. This process starts with the development of a Draft EIS (DEIS) which goes through a public comment period and consultation with other federal agencies before the development of the Final EIS (FEIS), which incorporates comments and identifies a preferred final project design. This process ends with the issuance of a Record of Decision (ROD), which specifies terms and conditions, such as environmental mitigation measures, that must be met by the offshore wind developer.

Incidental Take Authorizations (ITAs)

With certain exceptions, under the MMPA, it is illegal to “take” marine mammals without proper authorization from NOAA Fisheries or the U.S. Fish and Wildlife Service, where take is defined as “ to harass, hunt, capture, or kill or attempt to harass, hunt, capture, or kill any marine mammal.” (see *What is take?*). NOAA Fisheries shall issue a requested incidental take authorization (see *What federal and international laws protect whales?*) if take would be of small numbers, would have a negligible impact on the species or stock, and would not have an unmitigable adverse impact on the availability of the species or stock for subsistence use. Most incidental take authorizations have been issued for activities that produce underwater sound, including, but not limited to, military readiness, offshore wind development, coastal construction, and oil and gas activities (note commercial fishing is covered separately under the Marine Mammal Authorization Program).[129] Several offshore wind developers have applied for incidental take authorization for marine mammals for offshore wind pre-construction survey and construction activities. As NOAA Fisheries has stated explicitly, “NOAA Fisheries does not anticipate and has not authorized—or proposed to authorize—mortality or serious injury of whales for any wind-related action. To date, offshore wind developers have not applied for, and NOAA Fisheries has not approved, authorization to kill any marine mammals[130]. All active and proposed offshore wind-related incidental take authorizations can be found on NOAA Fisheries’ website.

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[129] More information on ITAs: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act

[130] NOAA FAQs: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/frequent-questions-offshore-wind-and-whales

Figure 18. Overview of permitting and authorization process for offshore wind developers under the purview of the Bureau of Ocean Energy Management (BOEM) and the National Oceanic and Atmospheric Administration (NOAA) Fisheries. Colors indicate the key agency/organization for each step in the process (blue= NOAA Fisheries, green=BOEM, black=developer).

Endangered Species Consultations

In addition to NOAA consultation under the MMPA and the ITA authorization process, the COP approval process includes Section 7 consultations with NOAA Fisheries under the ESA for listed (e.g., endangered or threatened) species (see *What federal and international environmental laws protect whales?*). For marine mammals in the U.S. Atlantic, this includes North Atlantic right whales, fin whales, and sei whales, as well as other marine species. The Section 7 consultation process begins with a determination that a listed species or designated critical habitat may be present in the action area (16 U.S.C. § 1536(c)(1); 50 CFR § 402.12(c)). If present, BOEM must develop a Biological Assessment (BA) to determine whether the proposed action may adversely affect endangered species or modify critical habitat. The BA considers all proposed federal actions associated with construction, operation and maintenance, and decommissioning, including BOEM COP approval, U.S. Army Corps of Engineers permits, Environmental

Protection Agency permits, and MMPA take authorizations,[131] including proposed actions to avoid, minimize, or otherwise mitigate effects to marine mammals. If there is a determination of potential adverse effects, NOAA Fisheries uses the BA, DEIS, and proposed MMPA ITA authorization to develop a Biological Opinion (BO; formal consultation). The BO includes a detailed analysis of the effects of the action and determines whether the proposed action is likely to jeopardize the species or destroy or adversely modify its critical habitat. The BO also includes the incidental take statement (ITS) delineating the number(s) of takes and measures to minimize the amount or extent of take. BOEM utilizes the BO and other agency input (related to other resources) to issue a Record of Decision (ROD) including anticipated conditions of approval.

Do federal agencies consider cumulative impacts of multiple offshore wind leases when granting permits relevant to marine mammals?

- Cumulative effects are considered in different ways under the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), and Endangered Species Act (ESA).
- For offshore wind development, the Bureau of Ocean Energy Management (BOEM) considers cumulative impacts during the NEPA process. To date, BOEM has developed an Environmental Impact Statement (EIS) for each offshore wind project, which considers the potential cumulative environmental effects of past, ongoing and reasonably foreseeable future actions. This includes consideration of all active commercial offshore wind leases at the time of EIS development. EISs also identify potential development alternatives and the relative environmental effects of these possible alternative scenarios. It does not, however, consider planned offshore wind areas that have not yet been leased.
- Incidental take authorizations under the MMPA are issued only if a determination is made that the taking incidental to a "specified activity" (as described in an application) will have a negligible impact on the affected species or stock of marine mammals (additional detail on this process is included in *What is "take"?*). NOAA Fisheries factors other past and ongoing anthropogenic activities into its impact analysis via inclusion of these impacts as part of the baseline upon which the negligible impact determination is made.
- Cumulative effects are considered during the ESA Section 7 consultation process for listed species. However, the definition of "cumulative effects" in this process does not include any future federal actions (e.g., future offshore wind projects); it only considers future non-federal actions. However, past/ongoing federal and non-federal activities serve as the baseline to which the cumulative effects from future non-federal actions are compared.

Detailed Answer

BOEM and NOAA Fisheries cooperate throughout the offshore wind permitting process as dictated by the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), and Endangered Species Act (ESA; see *What federal and international environmental laws protect whales?* and *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*).

National Environmental Policy Act (NEPA)

Cumulative effects under NEPA are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40

[131] Endangered Species Act Information Needs for Offshore Wind Energy Projects in the U.S. Atlantic: https://media.fisheries.noaa.gov/2022-02/ESA-InfoNeeds-OSW-GARFO.pdf

CFR § 1508.7). The development of an Environmental Impact Statement (EIS), required by NEPA for permitting of an individual offshore wind project, includes analysis of the direct, indirect, and cumulative effects of each alternative in a range of reasonable alternatives. An effects analysis is conducted for each alternative, which is a project of a similar technical character or functionality that will meet the purpose and need but could differ with regard to locations within the lease area, sizes, technologies, designs, time frames, or operational procedures. This process considers the direct and indirect effects of a particular action (in this case construction, operations, and decommissioning of the wind farm) on environmental resources, including marine mammals. It also considers the cumulative effects of the action that occur in combination with other actions (BOEM 2019). The Council on Environmental Quality (CEQ) regulations for implementing NEPA specify the need to include all relevant past, present, and reasonably foreseeable future actions and to focus on truly meaningful effects. This process involves identifying a series of impact-producing factors (IPFs) with cause-and-effect relationships between actions and relevant physical, biological, economic, or cultural resources, both in relation to offshore wind development and other anthropogenic activities (e.g., fisheries, oil and gas, military). Example IPFs for offshore wind include lighting from vessels, pile driving sound, and habitat creation from structure presence. They define the particular ways in which an action or activity affects a given resource (BOEM 2020). Specific to other offshore wind projects, current and reasonably foreseeable future activities consider all active commercial leases (BOEM 2019), but do not consider Wind Energy Areas or Call Areas that do not have executed leases. Even if areas have been proposed for leasing, BOEM does not consider them to be "reasonably foreseeable" until after the lease sale has occurred.

Marine Mammal Protection Act (MMPA)

Proponents of an activity expected to result in incidental "take" of marine mammals (see *What is "take"?*) must apply for an Incidental Take Authorization (ITA) from the appropriate federal authorizing agency (see *What marine mammal-related permits, approvals and authorizations do offshore wind developers get?*). The process of issuing Incidental Take Authorizations (ITAs) under the MMPA requires NOAA Fisheries (or U.S. Fish and Wildlife Service [USFWS] for specific species, including manatees, polar bears, walruses, and sea otters) to make a determination that the take will (1) have a negligible impact on the affected species or stocks of marine mammals, (2) take of individuals are small in number, and (3) that there will not be an adverse impact on the availability of the affected species or stock on subsistence use among other requirements (for more information, see *What is "take"?*).[132] Neither the MMPA nor NOAA Fisheries' codified implementing regulations require direct consideration of impacts from other non-project activities (such as the construction and operation of additional wind farms) on marine mammal populations. As such, the only way NOAA Fisheries factors other past and ongoing anthropogenic activities into its impact analysis is via inclusion of these impacts as part of the baseline upon which the negligible impact determination is made (54 CFR § 40338). This analysis also includes assessing and integrating contextual factors (e.g., species' life history and biology, distribution, abundance, and status of the stock; mitigation and monitoring measures; characteristics of the activities) in determining the overall impact and issuance of an ITA.[133]

Endangered Species Act (ESA)

A consultation with NOAA Fisheries (or USFWS depending on species) pursuant to Section 7 of the ESA is required to consider the effects of a federal action on ESA-listed species and critical habitat (see *What federal and international laws protect whales?* and *What marine mammal-related permits, approvals and*

[132] More information on incidental take: https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act

[133] More information on incidental take: https://www.federalregister.gov/documents/2021/06/25/2021-13501/takes-of-marine-mammals-incidental-to-specified-activities-taking-marine-mammals-incidental-to

authorizations do offshore wind developers get?). For offshore wind projects, there is a formal Section 7 ESA consultation as part of approval of the developer's Construction and Operations Plan.[134] Formal consultations require the federal action agency (in this case BOEM) to draft a Biological Assessment,[135] which assesses the impacts of the proposed activities on ESA-listed species and designated critical habitat. A formal consultation concludes with NOAA Fisheries/USFWS issuing a Biological Opinion. A Biological Opinion includes Reasonable and Prudent Measures[136] and Terms and Conditions[137] aimed at reducing the potential impacts of the project on ESA-listed species. Cumulative effects that are considered in the Biological Opinion include effects of future state, tribal, local, or private actions that are reasonably certain to occur within the action area (50 CFR § 402.02). It is important to note that, while there is some overlap, the ESA definition of cumulative effects is not equivalent to the definition of cumulative impacts under NEPA. The key difference is that reasonably foreseeable future actions by federal agencies are considered under NEPA, but not in the ESA Section 7 consultation process. As such, future offshore wind projects do not fit the ESA definition of cumulative effects and are not considered in cumulative effects analyses for Biological Opinions issued under Section 7 of the ESA (e.g., NMFS 2024a).

For More Information

- Section 7: Types of Endangered Species Act Consultations in the Greater Atlantic Region: https://www.fisheries.noaa.gov/insight/section-7-types-endangered-species-act-consultations-greater-atlantic-region

Glossary of Terms

This glossary defines and provides additional details on terms used in the Whale Communications FAQ document.

Amplitude- Distance between the resting position of a wave and its maximum displacement, measured in meters. Amplitude determines the volume of a sound, with higher amplitude sounds being louder and lower amplitude sounds being quieter. Loudness is also measured in decibels (dB) on a logarithmic scale. Also referred to as "volume" or "intensity".

Annual stranding rate – The number of strandings reported per year. It is important to note that the number reported may not accurately reflect the true number of strandings occurring each year.

Anthropogenic – Effects, processes, objects, or materials derived from human activities.

Authorization – Permit or approval from the federal government to conduct a specified action, which includes strict limits and requirements that must be complied with when conducting the action. For example, the NOAA Fisheries Office of Protected Resources issues Incidental Take Authorizations (ITAs) to U.S.-based entities under the Marine Mammal Protection Act for actions that unintentionally affect marine mammals (assuming the effect is on a small number of animals and leads to negligible impacts to

[134] In other scenarios Section 7 consultations can be resolved on an informal basis or be programmatic in approach.

[135] Endangered Species Act Information Needs for Offshore Wind Energy Projects in the U.S. Atlantic: https://media.fisheries.noaa.gov/2022-02/ESA-InfoNeeds-OSW-GARFO.pdf

[136] Reasonable and Prudent Measures are defined as steps deemed by federal agencies to be necessary and appropriate to minimize, monitor, document, and report the impacts of incidental take of threatened and endangered species.

[137] Terms and Conditions specify how to implement "Reasonable and Prudent Measures", including monitoring and reporting.

the species or stock). ITAs include requirements for how the entity is expected to ensure the least practicable impact, as well as monitoring and reporting requirements.

Bias (statistical) – Difference between an estimate of a parameter (e.g., estimated population size from survey data) and the true underlying value of the parameter (e.g., true population size). Statistical bias can arise during data collection, analysis, or interpretation. For example, if a boat-based survey is unable to collect observational data in a portion of a study area, the resulting abundance estimate could be statistically biased if appropriate analytical methods were not used to account for the unequal survey coverage.

Calving - Act of giving birth to a calf. "Calf" describes the young of many mammals, including whales.

Cetacean – Scientific name for the taxonomic subset of mammals that includes whales, dolphins, and porpoises. See "Marine Mammals" below.

Construction and Operations Plan (COP) – Plan that an offshore wind energy developer submits to the Bureau of Ocean Energy Management (BOEM) for approval to request a permit to build an offshore wind project. Includes substantial detail on project components and specifications, baseline survey efforts, and other data to inform BOEM's permitting decision.

Demography – Statistical study of populations. At the population level, demographic parameters may include characteristics such as a population's growth rate or age structure. Demographic parameters for individual animals include characteristics such as its age and sex.

Depleted- The Marine Mammal Protection Act (MMPA) defines a depleted marine mammal species or population as one that is below its optimum sustainable population level (i.e., animals are being removed from the population more quickly than they can be replenished).

Distribution – A species' arrangement in 3-dimensional space (e.g., latitude, longitude, and depth) within a particular time frame.

Dynamic Management Area (DMA) – A type of "slow zone" defined by NOAA Fisheries to help protect North Atlantic right whales from collisions. Mariners are encouraged to avoid these areas if possible, or to reduce speeds to 10 knots or less while transiting through these areas. NOAA Fisheries establishes DMAs based on visual sightings of three or more right whales within an area of 75 square nautical miles. Recently, NOAA has also identified "slow zones" based on passive acoustic detections of North Atlantic right whales; similar voluntary vessel speed slowdowns are encouraged in these areas, though these zones are not technically designated as DMAs.

Federal waters – Marine waters controlled by the U.S. federal government. Typically, this area extends from the boundary of state waters (3 nautical miles from the shoreline in the Atlantic Ocean) to about 200 nautical miles from shore (or to the boundary of other countries' waters).

Foraging – Refers to the act of animals spending time searching for food or eating.

Frequency - The number of times a sound wave's pressure repeats itself in a second, also referred to as "pitch". Higher frequency sound waves produce higher pitched sounds. Frequency is measured in Hertz (Hz) or kilohertz (kHz).

Geophysical surveys – Surveys in which vessels collect information about the ocean floor, including its geologic makeup and the features (shape and conditions) of the seafloor. Geophysical survey data inform planning of offshore wind farms, including cable routes, pile driving, and anchoring/mooring. Surveys can use various tools, such as high-resolution multi-beam or towed side-scan sonars, dual magnetometers, and high-resolution/shallow-penetration sub-bottom profilers, among others. Geophysical surveys are sometimes called “non-intrusive” because they do not involve physical sampling of the seabed, unlike geotechnical surveys (see below).

Geotechnical surveys – Surveys that physically sample or test characteristics of the seabed to inform the placement of offshore wind farm turbines, substations, and cables. Generally conducted after geophysical surveys, these physical samples and in-situ measurements of the seabed help create a geological model of the seabed to inform the engineering plans for offshore infrastructure.

Habitat – The physical, biological, chemical, and acoustic conditions that support the specific needs for a species' survival and reproduction. Habitat conditions may be constant or variable across space and time. For example, humpback whales undergo seasonal migrations from foraging grounds in the North Atlantic during spring through fall, to winter breeding grounds in equatorial waters. During these different stages, the properties of their habitat varies, as it is supporting different stages of the life cycle of the species.

Harassment – Type of incidental take under the U.S. Marine Mammal Protection Act (MMPA) that is authorized by NOAA Fisheries either through a Letter of Authorization (LOA) or an Incidental Harassment Authorization (IHA). Harassment authorizations are required for many types of anthropogenic marine activities, including aspects of offshore wind energy development. Also see “take,” below.

- **Level A harassment –** Any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild.
- **Level B harassment –** Any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, feeding, or sheltering. Changes in behavior that disrupt biologically significant behaviors or activities for the affected animal are indicative of take by Level B harassment under the MMPA.

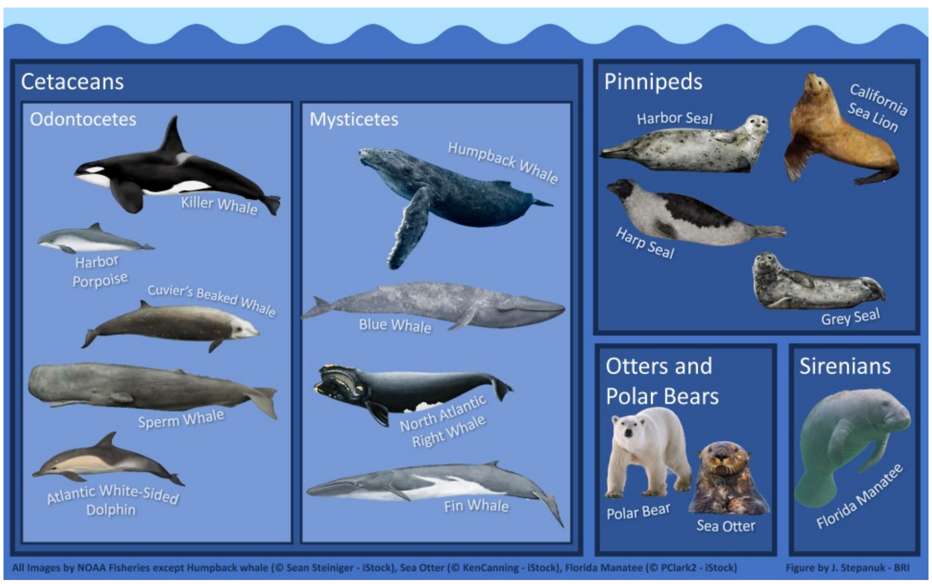
Human interaction evaluation – Process conducted during necropsies to assess and evaluate stranded animals for signs of human interaction, such as rope, gear, or debris on the animal, or sharp lacerations indicative of interaction with a vessel propeller. The process is documented in the “Handbook for Recognizing, Evaluating, and Documenting Human Interaction in Stranded Cetaceans and Pinnipeds” (Barco & Touhey 2006).

Intensity – See “amplitude”

Marine mammals – Marine mammals have characteristics of mammals (they breathe air through lungs, are warm-blooded, have hair for at least part of their life, and produce milk to nurse their offspring). However, they are unique from other mammals because they live most or all of their lives in or near the ocean. Marine mammals comprise four taxonomic groups:

- **Cetaceans:** Whales, dolphins, and porpoises. Cetaceans are carnivores who spend their entire lives in aquatic environments. They have streamlined bodies designed for swimming and diving, with appendages designed for aquatic environments. Cetaceans are comprised of two subgroups, odontocetes and mysticetes. Odontocetes are cetaceans with teeth, including all dolphins and porpoise, killer whales, beaked whales, and pilot whales. These species are typically fast-swimming animals who pursue one or a few prey items at a time, such as fish or squid. Mysticetes are cetaceans with no teeth. Mysticetes have vertical plates called baleen (made of keratin, the same material that comprises human hair and fingernails) that hang from the upper gum line of the mouth, used for filter-feeding of small prey. Mysticetes feed by either skimming the sea surface or by gulping huge amounts of prey and water and then filtering the water out of the mouth. Species in this taxonomic group include the largest whale species, such as blue and fin whales, as well as humpback, bowhead, and North Atlantic right whales.

- **Pinnipeds:** Seals, sea lions, and walruses. Pinnipeds are carnivores who have modified flippers to move on both land and in water. Though pinnipeds primarily forage and migrate in the water, they return to land or ice to breed, rest, and molt.
- **Sirenians:** Manatees and dugongs. Sirenians spend their entire life in the water and are herbivores. Though the fossil record suggests that there were once many species of sirenians, only four species exist today.
- **Marine fissipeds:** Polar bears and sea otters. Polar bears and sea otters are also considered marine mammals, though they are more closely related to terrestrial carnivores like weasels. They lack the types of adaptations seen in the other marine mammal taxonomic groups, but portions of their lives are associated and reliant on the marine environment. Therefore, they are considered marine mammals under U.S. laws.



Marine Mammal Health and Stranding Response Program – Program within the National Oceanic and Atmospheric Administration (NOAA) that was established under the U.S. Marine Mammal Protection Act to coordinate emergency responses to sick, injured, out of habitat, or entangled marine mammals. This coordination is achieved through collaborations with federal and state, local, and tribal governmental agencies, as well as an extensive network of regional stranding responders involving academic institutions, zoos and aquariums, museums, and non-governmental organizations.

Mitigation – Efforts to avoid, minimize, restore, or offset environmental impacts caused by a human activity. Mitigation of offshore wind energy-related effects to marine mammals could involve a wide range of approaches. Common mitigation methods for whales in relation to offshore wind energy development include vessel speed restrictions, observers on vessels, and noise reduction approaches such as bubble curtains.

Monitoring – Repeated, systematic observations of marine mammals or their habitat and ecosystems. Monitoring can be conducted for several purposes, including as part of scientific research, management, or to inform and enact mitigation measures (see "mitigation," above).

Morphology – Physical characteristics and structure of an animal. Morphological measurements may include body length, weight, or other information.

Mysticetes – Cetaceans with baleen instead of teeth, including large whale species such as fin, humpback, and blue whales. Also see "marine mammals" above.

Necropsy – The examination of an animal after death (essentially an autopsy on an animal), usually to determine the cause of death. A necropsy can involve observation, dissection, or sample processing. Resulting data may be used as a basis for interpreting and documenting cause of death. For marine mammals, necropsies provide opportunities to learn about the physiology, biology, and threats (e.g., disease, toxins) to individuals and populations, since many marine mammal species inhabit regions far from human activity and may be rarely seen when alive and healthy.

Noise abatement systems – Technologies implemented during pile-driving activities intended to reduce the distance and duration that sound travels through the water, and thus to minimize potential acoustic impacts to wildlife. Examples include bubble curtains and acoustic resonators that are deployed underwater around pile-driving activities to absorb sound.

Odontocetes – Cetaceans with teeth, including all dolphins and porpoise, as well as killer whales, beaked whales, and pilot whales. Also see "marine mammals" above.

Passive Acoustic Monitoring (PAM) – Study or monitoring method in which equipment is deployed in the ocean to record underwater sounds. The device is considered "passive" because it does not produce any sounds itself but rather listens and records sounds. These sounds can be classified by source (e.g., sounds generated by animals vs. waves, weather, vessels, etc.), and in the case of animal sounds, identified to species. PAM is an important method for studying cetaceans because it can be deployed for long periods of time (e.g., years), and can be used at night, during poor weather, underwater, and in other cases where direct visual observation is not possible or ineffective.

Pile driving – The process of installing structural columns into the seabed via a large hammer located on a barge. This process is used across a range of industries, including for installing some types of offshore wind turbine foundations. Monopile foundations (a single steel tube comprises a large part of the turbine foundation) are the most common type of offshore wind turbine foundation globally, since they are relatively inexpensive and easy to install in shallow waters. However, there are multiple turbine foundation types that do not involve monopiles (e.g., jacket foundations, floating foundations), and several newer pile-driving technologies that do not involve the use of a hammer (to reduce noise generation during turbine construction).

Pinniped – Seals, sea lions, and walruses. Also see "marine mammals" above.

Population – A marine mammal "population stock" or "stock" is the fundamental unit of conservation under the U.S. Marine Mammal Protection Act (MMPA). The MMPA uses the terms "population stock" and "stock" interchangeably to mean "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature." The term "population" is also sometimes used to mean a smaller geographic subset of a species that is being separately considered for research, management, or mitigation purposes.

Protected Species Observer (PSO) – Trained professional biologists who monitor aquatic animals that are federally protected under the U.S. Endangered Species Act (ESA) or Marine Mammal Protection Act (MMPA). PSO monitoring occurs during anthropogenic activities to help a wide range of industries comply with federal regulations.

Reasonable and Prudent Measures – Steps deemed by federal agencies to be necessary and appropriate to minimize, monitor, document, and report the impacts of incidental take of threatened and endangered species. These measures are listed in the Biological Opinion produced by NOAA Fisheries (or U.S. Fish and Wildlife Service) under the Endangered Species Act to assess the effects of proposed federal actions.

Seasonal Management Area (SMA) – A type of "slow zone" defined by NOAA Fisheries to reduce vessel collision risk to endangered North Atlantic right whales (per the Vessel Speed Restriction Rule of 2008; 50 CFR 224.105). SMAs occur in defined locations at specific times of year based on expected species presence or behavior. During these periods, vessels of 65 feet or greater in length are required to travel at a speed of 10 knots or less in these areas.

Seismic airguns – A technology that blasts the seabed with sound to find and explore offshore oil and gas reserves. The reflected waves or "echoes" from the airgun extend into the seabed and can be used to form a scan of the subsurface to locate fossil fuel reserves. Because the sounds must penetrate far below the surface of the seabed, airguns are substantially louder than the geophysical surveys used for offshore wind energy development (which do not need deep subsurface data).

Slow zone – Areas defined by NOAA fisheries to help protect North Atlantic right whales from collisions via avoidance and vessel speed restrictions. Types of slow zones include dynamic management areas (see definition), seasonal management areas (see definition), and slow zones similar to dynamic management areas but defined based on passive acoustic detections of North Atlantic right whales (as opposed to visual sightings).

Sonar – The use of sound propagation to understand the position and characteristics of underwater objects. Passive sonar involves only "listening", where underwater sounds are heard and characterized (e.g., some listening devices in military applications measure and characterize the frequency and vibrations of nearby vessels to determine nationality). For marine mammals, passive recordings of sounds produced by animals can be identified to species in many instances (see "passive acoustic monitoring"). Active sonar involves sound that is purposefully emitted from a source, which is then reflected or returned by measured objects. Active sonar can be used to obtain information about underwater objects, including their distance from the sound source, density, and speed. For example, echosounding emits a sound beam from a vessel directly downward to the seafloor, and the distance to the sea floor (e.g., water depth) can be estimated based on the amount of time it takes for the sound to return to the surface. Fishfinders are used to characterize the location (e.g., depth) of schooling fish, which work because the swim bladders of fish are of different density than water, which reflects sound in a unique way. For scientific purposes, more advanced versions of this technology rely on multiple frequencies of emitted sound and can be used to identify species or taxa, school size, and density of schooling animals like fish, shrimp, and zooplankton. Passive sonar does not contribute noise to the marine environment, as it just requires listening devices. Active sonar does add sound to the marine environment, which can vary in volume, pitch (i.e., acoustic frequency), and regularity (e.g., regular pulses vs. random noise introduction), depending on the intended application of the sonar technique.

Sound – Mechanical vibrations transmitted through an elastic medium (e.g., air, water). The ability of an animal to detect a sound depends on characteristics of the sound (e.g., frequency, intensity, duration), the proximity of the animal to the sound, and their hearing capabilities.

State waters – Marine waters controlled by a U.S. state. Atlantic coast states control areas within three nautical miles of the nearest ocean shoreline (including shorelines of islands). Beyond this boundary, waters are controlled by the federal government, though states may maintain some degree of authority via their NOAA-approved state Coastal Zone Management Plans.

Stock – See “population”.

Stranding – Marine mammals are considered stranded when found dead, either on land or floating in the water, or alive on land but unable to return to the water or in need of medical attention. Strandings can be caused by many factors, including disease, injury (e.g., from vessel strikes or entanglement with fishing gear), or other factors.

Take – As defined in the U.S. Marine Mammal Protection Act: “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” Take can be lethal or nonlethal, and can be intentional (e.g., whaling) or incidental (e.g., unintentionally occurring as a result of some other legal activity, such as energy development, fishing, military exercises, etc.).

Terms and Conditions – In the context of a Biological Opinion issued by NOAA Fisheries for an offshore wind energy development project, these specify how to implement “Reasonable and Prudent Measures”, including monitoring and reporting.

Unusual Mortality Event (UME) – Defined under the Marine Mammal Protection Act as a stranding event that is unexpected, involves a significant die-off of any marine mammal population, and demands immediate response. A working group of scientific experts use specific criteria to determine when a UME is occurring or has ended. Common causes of UMEs include infectious diseases, biotoxins, and human interactions.

Vessel speed restrictions – NOAA has implemented several management approaches to help protect endangered North Atlantic right whales from vessel collisions. These include designating locations where vessel speeds are restricted to reduce the risk of lethal collisions. Some restrictions on vessel speed are required in the same geographic locations and time periods every year (see “Seasonal Management Area (SMA),” above). Others are voluntary and designated based on known presence of animals in an area (see “Dynamic Management Area (DMA),” above). A 2008 vessel speed restriction rule requires vessels >65 feet to reduce speeds to 10 knots in SMAs and suggests voluntary speed reduction in DMAs. In 2022, NOAA proposed an amendment to the vessel speed restriction rule, which would (1) modify current SMAs, (2) apply speed restrictions to most vessels 35 feet or longer, and (3) create a new framework for implementing mandatory speed restrictions outside of active SMAs.

Vessel strike – When a vessel collides with marine animals such as whales.

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