The Dynamic Ocean

Offshore Wind Energy and Other Activities in the New York Bight

NEW YORK STATE OF OPPORTUNITY.
NYSERDA

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Acknowledgments

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Overview

New York State is striving to achieve 100% carbon-free electricity by 2040. To accomplish this, the expansion and diversification of renewable resources is critical. Renewable energy goals, such as New York's, are an essential strategy to promote this change, and offshore wind farms are a key element for meeting the State's renewable energy needs. However, the benefits and effects of offshore wind energy development must be evaluated in the context of other maritime activities and their combined effects on the environment.

Marine ecosystems are dynamic, with daily, seasonal, and annual variation in environmental conditions and in wildlife distributions. Many marine areas are heavily used for transportation, resource extraction, military exercises, and other activities[1]. Land-based human activities also impact marine ecosystems, such as coastal development and pollutants that make their way into oceans.

"Humanity relies on the oceans for survival, but our activities also impact the marine environment"

Offshore wind energy development is a new industry in the U.S. that is being introduced into this highly dynamic and human-influenced system. As such, it is important to consider the environmental and economic impacts of offshore wind within this context, and to understand—and try to minimize—conflicts among human uses, while protecting natural resources that are ecologically and economically important. New York State is committed to pursuing renewable energy development responsibly, and is using a range of strategies to accomplish this goal.

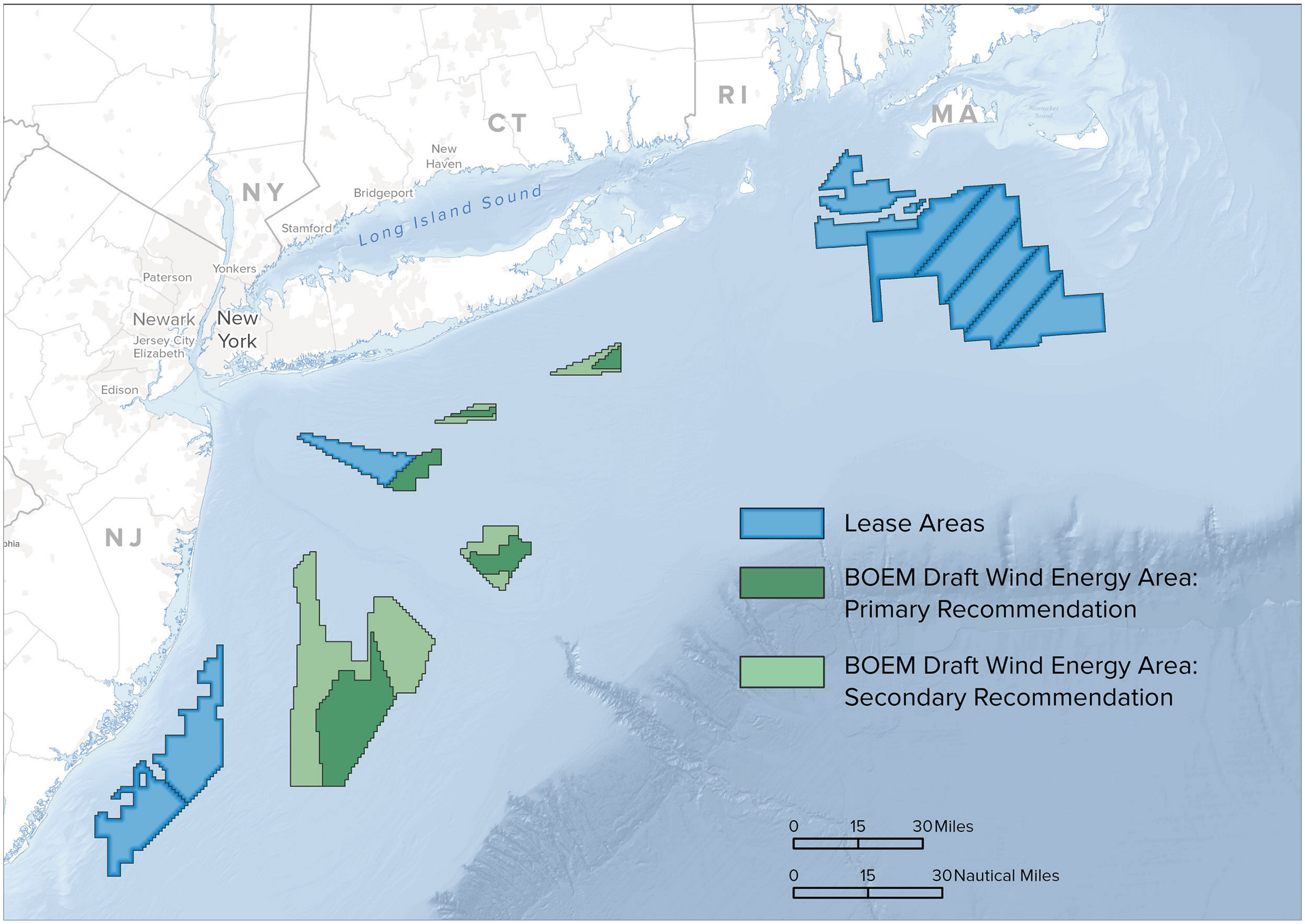


Figure 1: *Map of New York Bight region in the northeast United States, including wind energy lease areas and potential lease areas designated by the Bureau of Ocean Energy Management (BOEM). Credit: NYSERDA*

Overview

The Mid-Atlantic Bight Region

The Mid-Atlantic Bight, which contains the New York Bight (Figure 1), spans the offshore area from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina. The area is both ecologically and economically significant. The sandy, gently sloping continental shelf in this region extends up to 90 miles from shore and reaches about 650 feet in depth. This broad shelf area is generally bathed in cool Arctic waters brought south by the Labrador Current. Around Cape Hatteras, this southerly flow meets the warmer waters of the Gulf Stream. Beyond the shelf edge, the continental slope descends rapidly to a water depth of around 10,000 feet.

This region is an important area for a broad array of wildlife species due to high primary productivity[2] and its central location in a migratory pathway for many marine species along the Atlantic coast. Nutrient input from nearby rivers and estuaries, cold pool mixing (when cold, nutrient-rich waters from deeper in the water column are brought to the surface), and sunlight penetrating the water column provide suitable conditions to fuel the growth of phytoplankton, which forms the base of the marine food chain.[3–5] Phytoplankton blooms are followed by a pulse in secondary productivity – zooplankton species feeding on the phytoplankton – which then become food for larger species and drive the ecosystem's food web. The mid-Atlantic region is rich in small, schooling fish species (known as forage fish), which feed on the plankton and provide food for many larger predators, such as seabirds and marine mammals.

The Mid-Atlantic Bight sees major seasonal shifts in oceanography and the abundance and distribution of wildlife species across the annual cycle. High productivity and biodiversity drives commercial fishing and a broad range of recreational activities, including boating and sailing, sport fishing, whale-watching, and birding, all of which add significantly to the culture and economy of the area.

Human Impacts on Marine Wildlife

Humanity is reliant on the oceans for survival, but our activities cause a range of impacts to the marine environment. Human effects to wildlife, often inadvertent, can include:

1) Sensory disturbance. Underwater noise, vessel activity, and vibrations can change how wildlife experience the marine environment. These disturbances may affect an animal's ability to communicate, find food, rest, or perform other life functions.

2) Habitat change. Disturbance and changes to seabed ('benthic') habitats are caused by activities such as dumping of munitions. Changes in habitats may affect wildlife populations directly or indirectly. For example, impacts to prey populations may indirectly affect they predators.

3) Mortality or injury. Human activities can kill wildlife in a variety of ways, including vessel strikes, accidental entanglement in fishing gear, and exposure to contaminants or pathogens. Injuries and physiological changes can affect an individual's ability to function or successfully reproduce.

In many cases, these effects can be caused or exacerbated by climate change. For example, ocean acidification, which is directly linked to climate change, impacts the ability of shellfish to form their shells, thus reducing their growth and survival.[6,7] Changes in water temperature and water circulation patterns are affecting biological productivity and causing animals to shift their range, leading to effective habitat loss.[7] Thus, examination of human-caused impacts to wildlife and the marine environment must include consideration of climate change as a direct source of impacts, as well as a compounding influence on impacts from other sources.

Ecosystem-based Management

Ecosystems are comprised of interactions among plants, animals, and the physical environment. 'Ecosystem-based management' considers all of these interactions, rather than focusing on a single species or issue in isolation. For example, scientists and managers are increasingly using ecosystem-based approaches to understand factors that influence species distributions and movements. Understanding these ecological relationships facilitates the management of marine systems and can help minimize conflicts among human uses and between human and natural aspects of marine ecosystems, particularly in the face of human-induced environmental change.[8,9]

Humpback whales, gulls, and shearwaters feed on fish at Stellwagen Bank, Massachusetts. Rather than a focus on a single species, ecosystem-based management requires consideration of connections among species within an ecosystem. Credit: Getty Images

The Move Toward Offshore Wind Energy Development in New York

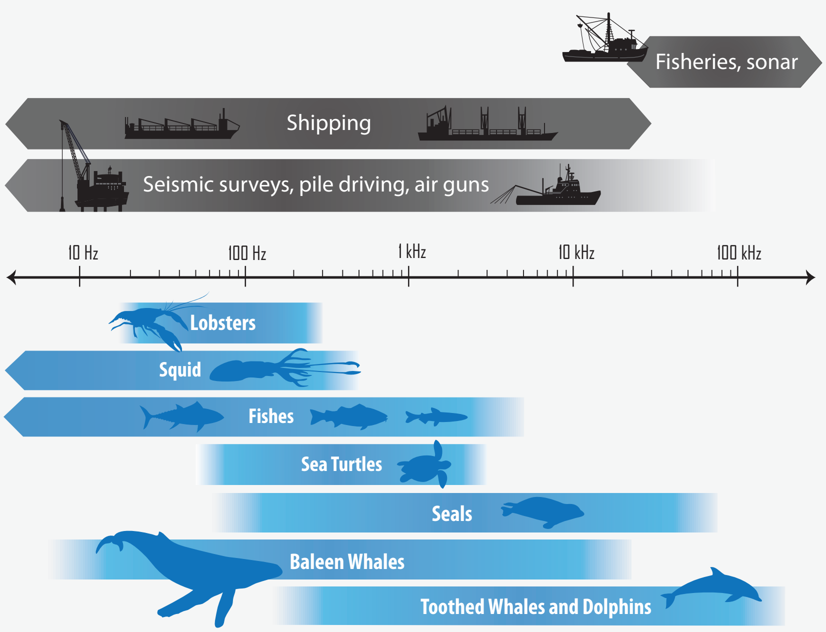
Europe is currently leading the way in offshore wind energy development, with 105 offshore wind farms across 11 countries as of 2018 (totaling over 4,500 turbines and 18.5 gigawatts of energy capacity).[10] Though the U.S. ranks second in the world in land-based wind energy,[11] the only offshore wind farm in the U.S. to date is the Block Island Wind Farm, a 5-turbine facility off the coast of Rhode Island. However, a number of large offshore wind projects are in the planning stages along the U.S. east coast, and locations such as the New York Bight are attractive for development due to strong, consistent winds and relatively shallow waters close to metropolitan areas with high electricity demand.

Through the New York State Ocean Action Plan, New York State is working to develop integrated and adaptive approaches to management in order to address stressors that threaten the ecological integrity of marine ecosystems.[12,13] New York State agencies, such as the Department of State (DOS), the Department of Environmental Conservation (DEC), and New York State Energy Research and Development Authority (NYSERDA) have been working for many years to support key research and assemble physical, biological, geographic, and socioeconomic information for the offshore waters of the New York Bight. Much of that work has informed the state's ecosystem-based management planning, including the recently-published New York State Offshore Wind Master Plan,[14] which charts a path for offshore renewable energy generation. As part of this plan, New York State is committed to understanding the potential environmental impacts of offshore wind generation within the context of other ocean uses and existing stressors to marine ecosystems, and to developing offshore wind energy generation in a way that minimizes impacts on the environment and other ocean users.

The following pages provide an overview of the ecological effects of offshore wind energy development and a few other well-studied human activities on the marine environment. A number of additional human influences are not addressed here in detail, such as military uses, mining/dredging, and the introduction and spread of invasive species, diseases, and pathogens.

With careful planning and an understanding of these stressors, conflicts among various human uses can be reduced while protecting natural resources.

Underwater Sound



Overlap in frequency ranges of marine activities and the hearing capabilities of marine wildlife species. Credit: Stenhouse/Biodiversity Research Institute

Sound is a pressure wave that passes through air or water, and is defined by its frequency (pitch), intensity (loudness), and duration. Underwater sound occurs naturally due to a variety of sources such as breaking waves, rain, and animal activity. Humans add additional noise to the underwater environment, which has the potential to impact wildlife in a variety of ways. Different species are capable of hearing and perceiving different frequency ranges at different intensities.

Noise carries much farther in water than in air—in certain cases, sound waves can travel hundreds or even thousands of miles underwater—and anthropogenic noise in the marine environment has been identified as a key threat facing many species. Many aquatic organisms use sound to navigate, communicate, and hunt for food.[15] *Wildlife may be injured by loud underwater noises, which can cause short or long-term hearing loss, changes in individual and social behavior, and can even affect reproduction.*[16–18] *A common effect is displacement, as animals move away from the source of noise, which may be temporary or lead to long-term changes in the distribution of populations.*[17,19]

Offshore Wind Energy Development

Offshore wind farms generally consist of wind turbines situated on foundations that rest in or on the ocean floor. Foundations can vary in design[20] but are generally accompanied by scour protections, or materials placed around foundations to prevent erosion of soft sediments (Figure 2). Offshore turbines tend to be larger than at onshore wind farms, with higher electricity production potential, and are expected to continue to increase in size in the future.[21] Electricity generated by turbines is conveyed via buried cables to above-water substations offshore and onshore.

Impacts to Wildlife and Ecosystems

Reliance on renewable resources for electricity – including offshore wind energy, which can be deployed on a large scale close to energy demand centers – is an essential strategy to combat climate change.[22,23] Offshore wind energy development has the potential to positively impact wildlife and ecosystems globally by reducing greenhouse gas emissions and other environmental impacts of fossil fuel use.[22]

"Wind energy is essential to combat climate change"

Offshore wind also has the potential to affect marine ecosystems and wildlife on a more local scale.[20] The infrastructure of offshore wind farms and associated characteristics, such as construction noise and vessel activity, have the potential to affect wildlife in several ways.

Noise and Other Sensory Disturbance

There are three primary sources of underwater noise at offshore wind farms:

1) geophysical surveys to assess the ocean bottom at a prospective development site;
2) wind farm construction, specifically the noise generated by driving the most common types of turbine foundations into the seabed (Figure 2); and
3) vessels associated with the wind farm.

Operational wind turbines also produce some underwater noise, but it is generally similar to, or below, levels of background noise.[24,25]

Porpoises at offshore wind farms in Europe move away from construction areas during pile driving activity and generally return once the noise ceases.[26] Several approaches have been developed to reduce construction noise, such as "bubble curtains" and other noise abatement systems.[27–30]

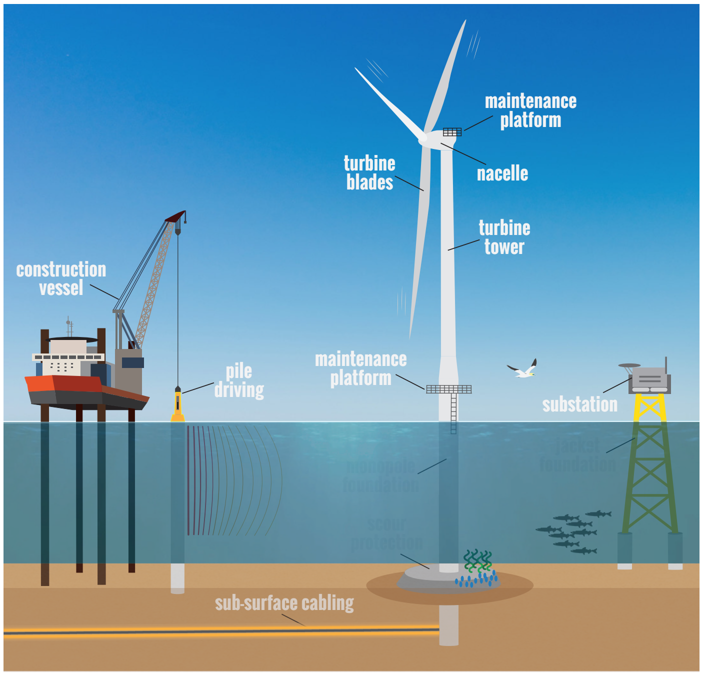


__Figure 2:__ Common elements of an offshore wind farm. During the construction phase, turbine foundations (for most foundation types) are driven into the seabed, and sub-surface cables are laid for electricity transport. The above-water turbine structure includes the tower, blades, and nacelle, with platforms for maintenance personnel. Below-water elements include the foundation, which may be a monopole or jacket foundation structure (among other types), and scour protection to prevent seabed erosion. Credit: Stenhouse/Biodiversity Research Institute

There are also "quiet" foundation types that do not require pile driving.[28]

Electromagnetic fields (EMF) from buried underwater cables also may cause some degree of attraction or avoidance in species on or near the seabed, though evidence for negative impacts is limited.[31,32] Some seabirds, like Northern Gannets, may avoid flying into turbine arrays,[33,34] while others, like cormorants and gulls, can be attracted to turbine platforms to roost.[35] Scientists are still trying to determine the cumulative effects of wildlife displacement from habitat that was used previously, such as energetic, reproductive, or survival costs.[36]

Habitat Change

Turbine foundations and scour protection provide hard substrates where marine organisms, such as mussels and seaweed, can grow. This phenomenon, known as 'artificial reef effect,' can attract fish and other species to the wind farm area. In Europe, scoters (sea ducks that eat mussels and urchins) were initially displaced from at least one offshore wind farm, but returned several years after construction, possibly due to new foraging opportunities around the turbines.[37] Seals have also been noted foraging

around offshore wind turbines in Europe,[38] and fish and sea turtles congregate around oil and gas platforms in the Gulf of Mexico.[39] However, it remains unclear whether these artificial reefs support new wildlife or simply aggregate animals already present in the surrounding environment.[40,41] Introducing new substrates into marine environments can facilitate the spread of invasive species[42] but can also enhance biodiversity and fisheries.[43] Site-specific environmental conditions appear to play a large role in determining the nature of observed changes in habitat.[44]

Direct Injury and Mortality

Wind farm construction and infrastructure can pose a direct threat to wildlife. For example, vessel activity associated with wind farms poses a risk of collisions with marine mammals and sea turtles.[45] Birds and bats may collide with turbines, though evidence for collision mortality is more limited offshore than for onshore wind farms.[41] Non-lethal disturbance, in which animals change habitat use patterns, appears to be a more common effect.

The Broader Context

Scientists are still evaluating the risks and effects of offshore wind energy development on wildlife. This is particularly true for wildlife populations off the coast of the U.S., where there is limited experience with this type of development. The effects of offshore wind energy are not introduced in a vacuum, and will interact with a host of other human activities in the marine environment. For example, there are many anthropogenic sources of underwater noise, and noise from wind energy development could, under some conditions, exacerbate this existing issue for acoustically sensitive species. Renewable energy also has environmental benefits, especially where it displaces fossil fuel extraction, transportation, and combustion that produce a range of pollutants, such as mercury[46] and carbon dioxide, the primary driver of climate change.[23,47]

New York initiated work on the Offshore Wind Master Plan in 2016, conducting environmental research, outreach, and planning to prepare for offshore wind development. With the publication of the Plan in 2018, the State has identified a roadmap to advance the responsible and cost-effective development of offshore wind resources in a way that protects the environment, as well as maritime, tourism, and fishing industries, and that advances the interests of local communities. In order to accomplish this, the potential impacts of offshore wind on marine wildlife are being considered within the context of climate change and other human activities.[12]

The 'artificial reef effect': mussels growing on the foundation of a wind turbine at the Block Island Wind Farm: Credit: AWEA

Flock of shorebirds near a wind farm in the North Sea, Germany. Credit: Getty Images

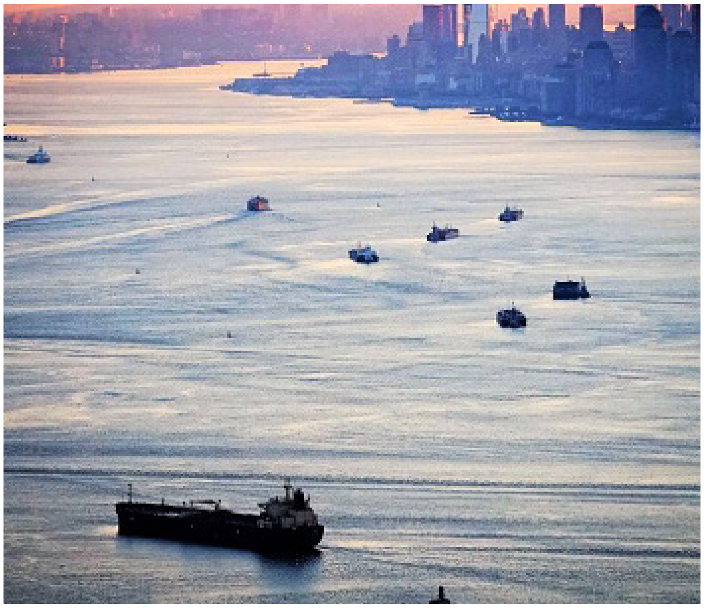
Shipping & Navigation

Shipping across the oceans is a major driver of most economies. The number of vessels in the worldwide shipping fleet has increased by approximately 13% in just the past decade, with growth projected to continue.[45] Shipping is responsible for relatively low fossil fuel emissions compared with other forms of transport, but it can have significant impacts on wildlife and marine ecosystems. These impacts are concentrated in the world's busiest ports and shipping lanes, including the ports of New York and New Jersey, which together rank as the 3rd busiest container port in the United States.[8]

Impacts to Wildlife and Ecosystems

Environmental risks of marine shipping include mortality, due to oil spills and collisions with vessels; behavioral disturbance, due to increased noise; and habitat change and degradation. Tankers are used to transport crude oil around the world, resulting in millions of tons per year of petroleum released into marine systems.[49] Oil spills cause mortality of seabirds and other wildlife,[49] and affect ecosystem structure and function.[50] Vessel traffic can cause mortality to marine mammals and sea turtles due to collision. One of the leading causes of mortality for the critically endangered North Atlantic right whale is collision with ships,[51] and other species are also at risk.

Vessels are one of the primary sources of aquatic noise pollution,[52] which can mask important acoustic signals (e.g., social interactions, navigation), cause behavioral changes, and in some cases affect individual health and reproduction.[13,15,16] In addition, many introductions of invasive species have been attributed to trans-oceanic shipping, as species can easily be transported in a ship's ballast or attached to the hull.[53] Shipping traffic can also degrade natural wetlands, seagrass beds, and other sensitive areas around ports.



Shipping traffic in New York Harbor. Credit: Getty Images

The Broader Context

The scale of shipping and navigation in the marine environment, and recognition of the inherent environmental risks, has led to several initiatives to mitigate impacts. Most single-hulled oil tankers like the Exxon Valdez, which spilled over 10 million gallons of oil off the coast of Alaska, have been phased out of production to reduce the risk of such catastrophes in the future. Speed restrictions have been implemented to reduce vessel collisions with North Atlantic right whales,[54] and efforts are underway to develop noise standards and noise reduction techniques for shipping.[55] Due to the complexity of the ocean environment, risks imposed by shipping can interact with other stressors to have compounding effects on species and the ecosystem.

The North Atlantic Right Whale

The North Atlantic right whale is one of the most endangered species in the world, with just over 400 individuals as of 2018.[56] These whales make a long distance journey from their summer breeding area, between Cape Cod and Nova Scotia, to winter calving areas in coastal Florida and South Carolina. This migration takes them through areas of heavy recreational and commercial vessel traffic.

To reduce collisions between right whales and vessels, dynamic management areas have been established, shipping lanes have been narrowed, and vessel speed restrictions are implemented at certain locations and times of year for all vessels 65 feet or longer.[57] In addition, all boaters are required by law to remain at least 1,500 feet (460 m) away from right whales.

Credit: Florida Fish and Wildlife Conservation Commission, NOAA Research Permit # 594-1759

Fishing

Commercial and recreational saltwater fisheries are long-standing industries in the New York Bight, as well as significant elements of the region's coastal culture and tradition. In the broader Mid-Atlantic region, these industries land millions of pounds of fish and shellfish (mollusks and crustaceans) annually, worth several hundred million dollars.[58] Catches are generally used for human consumption, but include other uses such as bait, animal foods, and omega–3 oils. The commercial fishing industry is highly regulated. Individual states issue licenses and permits. NOAA Fisheries and the Atlantic States Marine Fisheries Commission establish annual catch limits and quota allocations for harvested species, dictate size limits, and introduce geographical and temporal restrictions for fisheries.

"Fishing is a long-standing industry in the New York Bight, and a significant element of the State's coastal culture and traditions"

Impacts to Wildlife and Ecosystems

Many types of fisheries are present in the New York Bight. While gear is designed specifically for target species, fishing vessels and fishing gear can impact the marine ecosystem in a variety of ways, including: bycatch and incidental entanglement of non-targeted species, such as other fish, seabirds, sea turtles, and marine mammals;[59–62] habitat loss or modification to the seabed and to benthic communities;[63–65] derelict gear (i.e. abandoned, lost, or otherwise discarded fishing gear), which can continue to trap animals;[66–68] overexploitation of target species;[69–71] and vessel traffic, which introduces noise and the risk of collisions with wildlife.

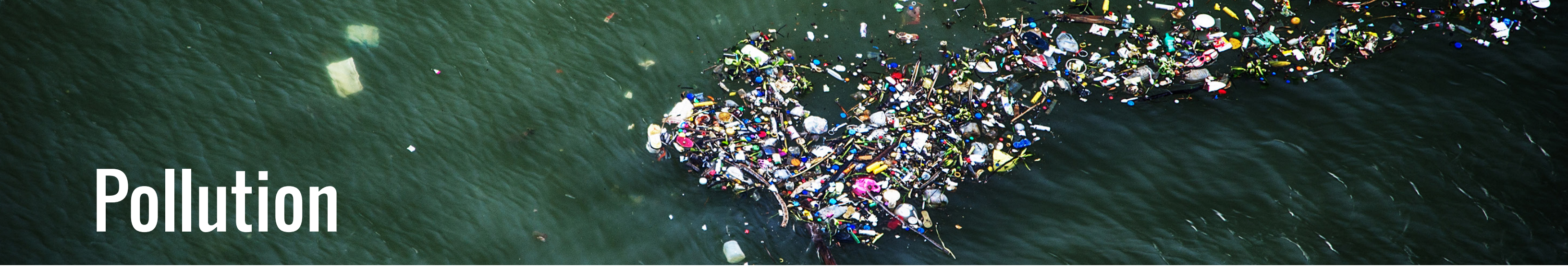
Aquaculture – the practice of farming fish, shellfish, plants, and other aquatic organisms in cages, pens, or tanks – provides an alternative to harvesting wild stocks, and is a growing industry on the Atlantic coast. These operations can also impact the local environment, including the introduction of non-native species, diseases, parasites, and pollution.[72]

The Broader Context

Many marine species are impacted both directly and indirectly by fisheries, though work is being done to reduce impacts to wildlife.[59,71,73–75] Fishing patterns change from year to year, and even within a season, in response to factors such as current regulations (e.g., quotas, closures, marine protected areas), market price, weather, and variation in the abundance and distribution of target species. Due to this variability, the extent of the effects on populations also varies over space and time and is difficult to measure or regulate. Thus far, fisheries productivity in the northeastern U.S. has been affected by climate change to a much lesser degree than many other parts of the world,[76] though as global temperatures continue to rise, it is unclear whether this pattern will continue. The dynamic nature of fishing activities also has the potential to conflict with fixed-location activities such as mining and energy development, though there are a variety of spatial planning efforts to prevent or minimize conflicts.[77] Through outreach and open dialog, New York State is committed to engagement with commercial and recreational fishers to reduce conflict between offshore wind energy development and other human uses.[12]

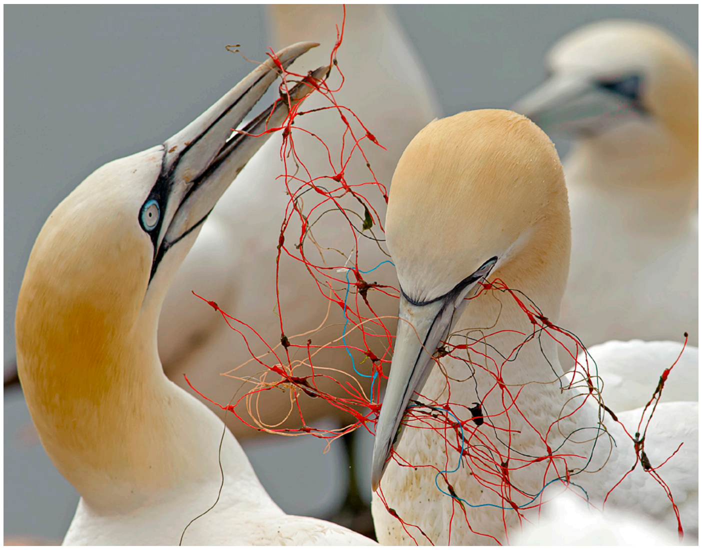
Fisherman emptying a trawl net full of fish. Credit: Getty Images

Sea turtle entangled in derelict fishing gear. Credit: Getty Images



Pollution

Pollution in the marine environment comes in many forms, and has cumulative negative effects on marine ecosystems.[78] Aquatic noise and artificial light are both considered types of pollution. More commonly, however, pollution is either organic (e.g., nutrient runoff from agricultural fertilizers) or inorganic (e.g., plastics).



Northern Gannets and other marine species encounter marine debris regularly. Credit: Getty Images

Impacts to Wildlife and Ecosystems

The introduction of organic pollutants into aquatic environments can trigger a cascade of negative events, leading to algal blooms (such as 'red tides'),[79–81] shellfish area closures,[82] and fish die-offs.[83] Certain types of pollutants can biomagnify and bioaccumulate within a food web; contaminants accumulate in the tissues of an individual, eventually reaching levels that are harmful to both the individual and its consumers,[84,85] and these concentrations increase from one step in the food web to the next (Figure 3).[86] Top marine predators, such as tuna and swordfish, can accumulate levels of contaminants deemed unsafe for human consumption.[87]

Macroplastics, such as derelict fishing gear, have visible impacts and repercussions for both human economic interests (i.e., fishing and tourism)[88,89] and wildlife health (i.e., mortality or injury through entanglement and ingestion).[90,91] In 2015, the global production of plastics reached 381 million metric tons.[92] Up to 10% of all plastic material ultimately ends up in the ocean, where it accumulates and persists for long periods of time.[93]

Microplastics are particles smaller than a quarter of an inch (5 mm) that typically result from the degradation of larger materials. Microplastics are ingested by many species, which in some cases may mistake colorful plastic pieces for prey items.[94] Ingestion can reduce stomach capacity, affect growth, and cause internal injury or death.[95] Other contaminants in the water adhere to the surface of microplastics, making ingestion even more harmful.[88] Ingesting a single piece of plastic causes seabird mortality in about 20% of cases; seabird and sea turtle mortality is even higher for soft debris such as balloons.[96] Both organic and inorganic pollution have compounding effects on marine habitats and ecosystem health.

"Up to 10% of plastic material ultimately ends up in the ocean"

The Broader Context

Airborne pollutants, such as heavy metals and Polychlorinated Biphenyls (PCBs), are released into the atmosphere and can be carried far from their original source.[97,98] Likewise, marine debris can have wide-ranging origins. Due to ocean currents, most debris ultimately ends up in one of the five major oceanic gyres,[88] leading to the infamous "garbage patches" in remote areas of the world's oceans.

Several initiatives aim to reduce global waste inputs into the ocean, educate the public, and actively remove plastics and other debris.[99,100] Wetland restoration has helped remove excess nutrients and organic compounds from agricultural runoff before they reach larger waterbodies,[101,102] and there are multiple initiatives to reduce single-use plastics, such as straws and plastic bags. However, as the global population continues to grow, and the number of non-biodegradable consumer products rises, pollution of the marine environment is likely to remain a common stressor on marine wildlife and ecosystems.

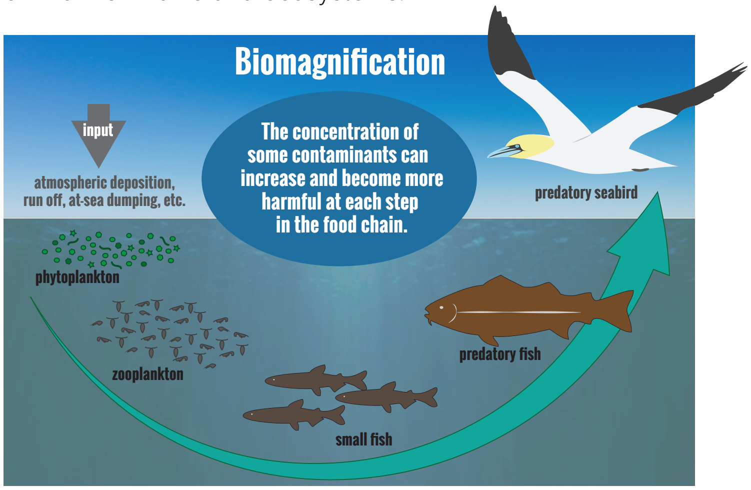


Figure 3: *The process of biomagnification where the concentration of contaminants increases and becomes more harmful with each step in the food chain. Credit: Stenhouse/Biodiversity Research Institute*

Climate Change

The Earth's climate is undergoing rapid changes. Over the last century, the average global temperature increased about 0.8–1.2°C and is predicted to increase by 1.5 °C by the middle of this century.[23] Atmospheric concentrations of greenhouse gases, including carbon dioxide (CO_2), have increased substantially compared to pre-industrial levels,[103] global sea levels have risen, and surface water temperatures and ocean acidification have increased while salinity levels have decreased. Climate change is also driving changes in large-scale weather patterns, including increases in the frequency and strength of extreme weather events.

"Without drastic reductions in greenhouse gas emissions, existing fisheries and other human uses of the oceans will be dramatically impacted"

Due to these climate impacts, the International Panel on Climate Change estimates that a large fraction of the earth's species are at increased risk of extinction.[104] As oceans are responsible for absorbing >80% of heat added to the global system,[105] the marine environment is significantly impacted by these changes.

Impacts to Wildlife and Ecosystems

Ocean acidification can reduce the ability of species like clams and oysters to form shells, and reduce the survival of fish eggs and larvae.[106,107] Ocean warming in the northeastern U.S. is occurring three times faster than the global average,[108] and increased temperatures can cause range shifts and decreased survival in species like the Atlantic surfclam.[109] Rising ocean temperatures and increased CO_2 levels have also been associated with changes in primary productivity,[106] dissolved oxygen depletion,[6] range expansions of invasive species,[110] and increased disease prevalence[111] in marine ecosystems.

Emissions from a fossil fuel-powered plant: Credit: Getty Images

All of these impacts can cause declines in economically important species[106,112] and alter the composition and functioning of ecosystems.[6]

Climate change in the marine environment is perhaps most visible through changes in habitat availability.[6,23,104] Habitat loss refers not only to the physical features of an animal's environment, but also an animal's ability to live in that environment based on prey availability and climatic conditions. As ocean temperatures warm, species ranges shift and contract, and this loss of habitat can have cascading effects through entire ecosystems and, ultimately, result in the reduction or disappearance of species.[113] While some species can adapt by shifting their distributions, others, including some whales and dolphins, will be at much higher risk of extinction.[114]

The Broader Context

Long-term climate projections suggest that without drastic reductions in greenhouse gas emissions, existing fisheries and other human uses of the oceans will be dramatically impacted. Wildlife will also be impacted – with the potential for large-scale extinctions, range shifts, and other population and ecosystem changes.[115] Renewable energy, including wind energy, has been identified as one of the best options available to combat climate change.

Habitat Loss and The American Lobster

Unprecedented warming in the northwest Atlantic since the 1980s has led to a shift in suitable habitat for the American lobster, the most valuable single-species fishery in the U.S. As ocean temperatures warmed, habitat was reduced for juvenile lobsters and disease increased in the southern part of their range. These trends resulted in the collapse of the fishery in southern New England and Long Island Sound.[116,117]

Credit: Getty Images

Human Impacts to Marine Wildlife

There are substantial seasonal, annual, and long-term changes in the abundance and distribution of marine wildlife, due to natural variations in oceanographic factors such as water temperature, currents, prey availability, migratory patterns, and broad-scale climate patterns. Human activities further affect fishes, marine mammals, seabirds, and other wildlife. Natural resource management must consider both wildlife and human uses of the oceans.

Fortunately, marine systems and wildlife can be resilient. By recognizing the importance of the roles that different species play in ecosystems, as well as the impacts of multiple human stressors, management strategies can be implemented to reduce the effects of these stressors. Vessel traffic, underwater noise, habitat change, and changes to food webs are persistent concerns, but in some cases, strategies developed to reduce the impacts of one industry or situation may also be applicable to others.

Vessel traffic

Vessel traffic associated with fisheries, shipping, military exercises, and other activities can impact marine wildlife through noise and increased risk of collisions. Collisions are the second leading anthropogenic cause of death for large whales,[118] but speed restrictions and rerouting shipping lanes can help reduce collision mortality. Efforts to improve communication of whale sightings between users of the offshore environment, such as vessels associated with offshore wind energy development, can further reduce the chances for impacts.

Underwater noise

Underwater noise, including that from increased vessel traffic, the use of sonar (sound waves used to detect objects or navigate underwater), seismic surveys, and pile driving during the construction of offshore wind farms, can cause sensory disturbance to wildlife. While the impacts of noise depend on many factors including intensity and frequency, noise can affect aquatic species' communication, increase their vulnerability to predators or affect their ability to catch prey, cause displacement or avoidance behaviors, and in extreme cases, can cause tissue damage and mortality.[119]

Marine mammals are particularly vulnerable to underwater noise. While most military sonar operates primarily at mid-frequencies, low-frequency sonars are being developed which travel greater distances in the ocean and operate at frequencies much closer to those of whales, including humpback whales and critically endangered North Atlantic right whales.[120] Military sonar can be powerful enough to

Humpback whale lunge feeding on Atlantic menhaden in front of a tanker outside Long Beach, New York. Credit: Getty Images

affect the behavior and physiology of marine wildlife. It can deafen marine mammals, and has been correlated with strandings of whales and dolphins, as they seemingly become disoriented and/or beach themselves.[121]

"Ecosystem-based management relies on understanding and addressing impacts from multiple stressors"

While most research has focused on fish and marine mammals, scientists and resource managers are beginning to examine the underwater hearing capabilities of other wildlife, such as seabirds[122] and invertebrates,[123] that may also be impacted by anthropogenic noise in the ocean.

Researchers are working to better understand the extent and impacts of noise pollution, including research on anthropogenic noise and whale calls in the New York Bight,[124] and to develop source-quieting methods and alternative technologies to reduce the impacts of sonar and other noise on wildlife.[125] Noise-dampening technologies for pile driving, for example, can be used during the construction of offshore wind farms.[28,29]

Habitat Change

The loss and degradation of habitat is caused by fishing, sand mining and dredging, pollution, and climate change, among other sources. Some habitat damage can be addressed using targeted mitigation strategies, such as modifications to fishing gear.[126] Indirect effects, such as the disappearance of suitable prey following increases in water temperature, are often harder to address. Knowledge and recognition of these issues is the first step towards developing solutions.

Habitat created by introducing new structures, such as turbine foundations, into the marine environment may enhance opportunities for some species, like mussels. These species can in turn attract predators to these areas, known as a 'reef effect'.[127] Understanding the impacts of both loss and creation of habitat, and how these changes influence ecosystem dynamics, is important to inform decisions about natural resource management.

Changes to Food Webs

Food webs are often complex and interdependent. Because of this, disruptions such as the introduction of invasive species, the depletion of apex predators, or the collapse of an important prey species can reverberate through food webs in an unpredictable manner. For example, overfishing of cod in the western North Atlantic caused explosions of sea urchin populations, which in the middle part of the last century wiped out kelp forests that provide important shelter for lobsters and many fish species.[128] Recognizing these changes at the ecosystem scale can be a slow process, but a stronger focus on ecosystem-based management can begin to mitigate broad-scale impacts.

Summary

The environmental effects of offshore wind development are still being investigated, but they must be considered within the context of a highly dynamic marine ecosystem. The distributions and movements of marine wildlife are constantly changing due to natural variations in oceanographic factors, such as water temperature. Climate change, as well as human activities, can also affect these systems. It is important to understand the effects of these activities and their interactions in order to minimize conflicts among human uses and between human and natural aspects of marine ecosystems.

Bubble curtain being used to mitigate sound levels from pile driving during construction of a wind farm in Germany in 2012. Credit: Trianel GmbH

Reducing Conflicts in a Dynamic Ocean

Ecosystem-based management, at its core, relies on understanding and addressing impacts from multiple stressors and recognizing that ecosystems are not defined or constrained by political boundaries.[10] Managing marine ecosystems requires collaboration among ocean users and across regional and national jurisdictions. New York State recognizes the necessity of working collaboratively with other states and stakeholder interests, and considering offshore wind energy development in the context of existing ocean dynamics.

Marine Spatial Planning

'Marine spatial planning' is an important strategy to reduce conflicts among human uses and between humans and wildlife. It involves (1) the collection, assessment, and aggregation of spatial data for the offshore environment, and (2) the combination of data from different sources to inform planning and ecosystem management.[129] Marine spatial planning often incorporates oceanography and biodiversity information, habitat classifications, and current human uses, among other data, which are combined to find management solutions (Figure 4).

Careful marine spatial planning can reduce conflict between different human uses of the ocean and provide a clear avenue for the inclusion of wildlife data into decision-making processes. There are numerous examples of this, from strategies for reducing fisheries bycatch to rerouting shipping activity around key North Atlantic right whale habitats. Understanding the effects of different stressors on wildlife is a key aspect of marine spatial planning. Integrating ecosystem and human considerations into natural resource management can conserve the ecological integrity of marine ecosystems while also contributing to local economic and social well-being.[129]

In the Mid-Atlantic Bight, several marine spatial planning efforts are underway. In addition to state-specific efforts, regional ocean councils made up of federal, state, and tribal members conduct data sharing, analysis, and planning activities. The Mid-Atlantic Regional Council on the Ocean (MARCO),[130] which includes states from New York to Virginia, is focused on climate change adaptation, identification of important marine habitats, improving water quality, and planning for renewable energy development.[131]

A New Industry in the New York Bight

Offshore wind energy development can affect wildlife in the offshore environment, and potential impacts are still being investigated within the context of a highly dynamic and human-influenced marine ecosystem. Offshore wind development also poses potential benefits to wildlife and ecosystems by broadly helping to mitigate the effects of climate change. The environmental consequences

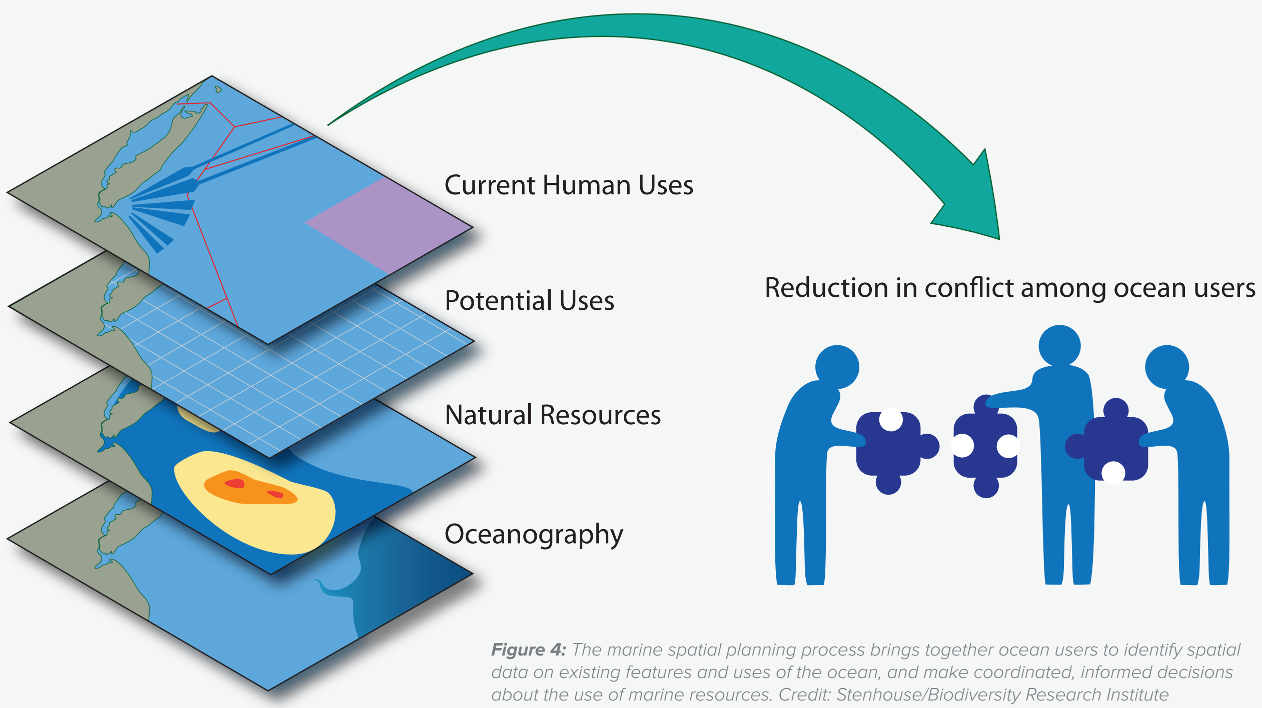


Figure 4: The marine spatial planning process brings together ocean users to identify spatial data on existing features and uses of the ocean, and make coordinated, informed decisions about the use of marine resources. Credit: Stenhouse/Biodiversity Research Institute

of maintaining the status quo – contributing toward an expected global temperature change of greater than 1.5°C – are likely to be catastrophic. Recognizing the risks associated with climate change, many countries around the world are taking action to curb the use of fossil fuels.

In the U.S., states like New York are leading this effort. New York State has a goal of 100% carbon-free electricity by 2040 and a net-zero carbon economy by 2050. NYSERDA is helping to develop offshore wind farms to meet energy needs while reducing environmental impacts from fossil fuels. New York is engaging in marine spatial planning through multiple efforts, including the development of the New York State Offshore Atlantic Ocean Study, the Offshore Wind Master Plan, and the New York Ocean Action Plan.[10,12,132] This process includes extensive and ongoing scientific research, public engagement across stakeholder groups, including environmental and fisheries groups, and collaboration with other states in the region, to aid in our understanding of the potential environmental impacts of offshore wind development and to develop strategies to reduce conflict among ocean users. For example, NYSERDA is working closely with fisheries stakeholders to better understand movement of fishing vessels through the New York Bight to address the potential need for transit lanes through offshore wind farms.[77]

Gulls in flight in New York Harbor. Credit: Getty Images

New York is committed to understanding offshore wind generation within the context of climate change and other existing stressors to marine wildlife, and to developing offshore wind energy in the New York Bight in an environmentally responsible way that minimizes impacts to wildlife and other human uses of the oceans.

Stakeholder engagement at the New York State Offshore Wind Update Public. Information Meeting, Long Island, May 7-8 2018. Credit: NYSERDA

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Glossary of Terms

Acidification – decrease in the pH of water, caused by the absorption of carbon dioxide (CO_2) from the atmosphere

Anthropogenic – human-caused

Aquaculture – the farming of aquatic species in a controlled marine or freshwater environment

Artificial reef effect – attraction of marine species to man-made underwater structures that represent new habitat (e.g., hard substrate) on which algae and invertebrates can grow

Ballast – heavy material, often water, which is held low in a boat to provide stability; adjustment of ballast (adding water into ships' tanks or discharging it into the ocean) can inadvertently spread invasive species

Benthic – relating to or occurring at the bottom of a body of water, including sediments on the ocean floor

Bioaccumulation – accumulation of a contaminant in the body of an organism or between organisms in a food chain

Biodiversity – the variety or variability of life, measured through genetics, species, and ecosystems

Bycatch – the incidental capture of non-target species during fishing; can include species in the marine environment such as seabirds, sea turtles, and marine mammals, as well as other fish species

Cold pool mixing – waters that enter the Mid-Atlantic Bight from the north form a "cold pool" layer at the bottom of the water column; in the fall and winter, mixing occurs between the cold pool and surface layers, bringing these nutrient-rich waters to the surface and fueling primary productivity

Community – a naturally occurring group of species interacting and occupying a habitat

Disturbance – disruption of existing conditions for an organism or its habitat; generally is not directly lethal, but can affect wildlife in a variety of often negative ways

Ecosystem – a biological community of plants and wildlife and their physical environment

Ecosystem-based management – an integrated management approach that considers interactions within an ecosystem rather than single species or issues in isolation

Food web – a system of interconnected or interdependent food chains

Frequency – the wavelength of a sound that determines the sound's pitch (measured in hertz or kilohertz)

Gyre – a large system of circulating ocean currents

Invasive species – a species that is not native and causes ecological or economic harm when introduced to a new environment

Marine spatial planning – process that brings together ocean stakeholders to share information, allowing for more coordinated ecosystem management and development decisions for the offshore environment

NOAA – National Oceanic and Atmospheric Administration

Oceanography – the science of the geological, chemical, and physical properties of the ocean

Overexploitation – overharvesting a renewable resource until there are diminishing returns, potentially leading to loss of the resource

Pathogen – a bacterium, virus, or other microorganism that may cause disease

Physiology – the functions and activities of a living organism or its body parts; includes physical, biological, and chemical phenomena

Plankton – small organisms that float in the ocean, including phytoplankton (microscopic plants that produce energy from the sun) and zooplankton (tiny animals, including small crustaceans and the eggs and larvae of larger animals)

Pile driving – the process by which a monopile wind turbine foundation is driven into the seabed during construction

Productivity – rate of generation of new biomass in an ecosystem. Primary productivity is the creation of energy from sunlight (photosynthesis) in plants and algae that form the basis of the food chain

Salinity – saltiness

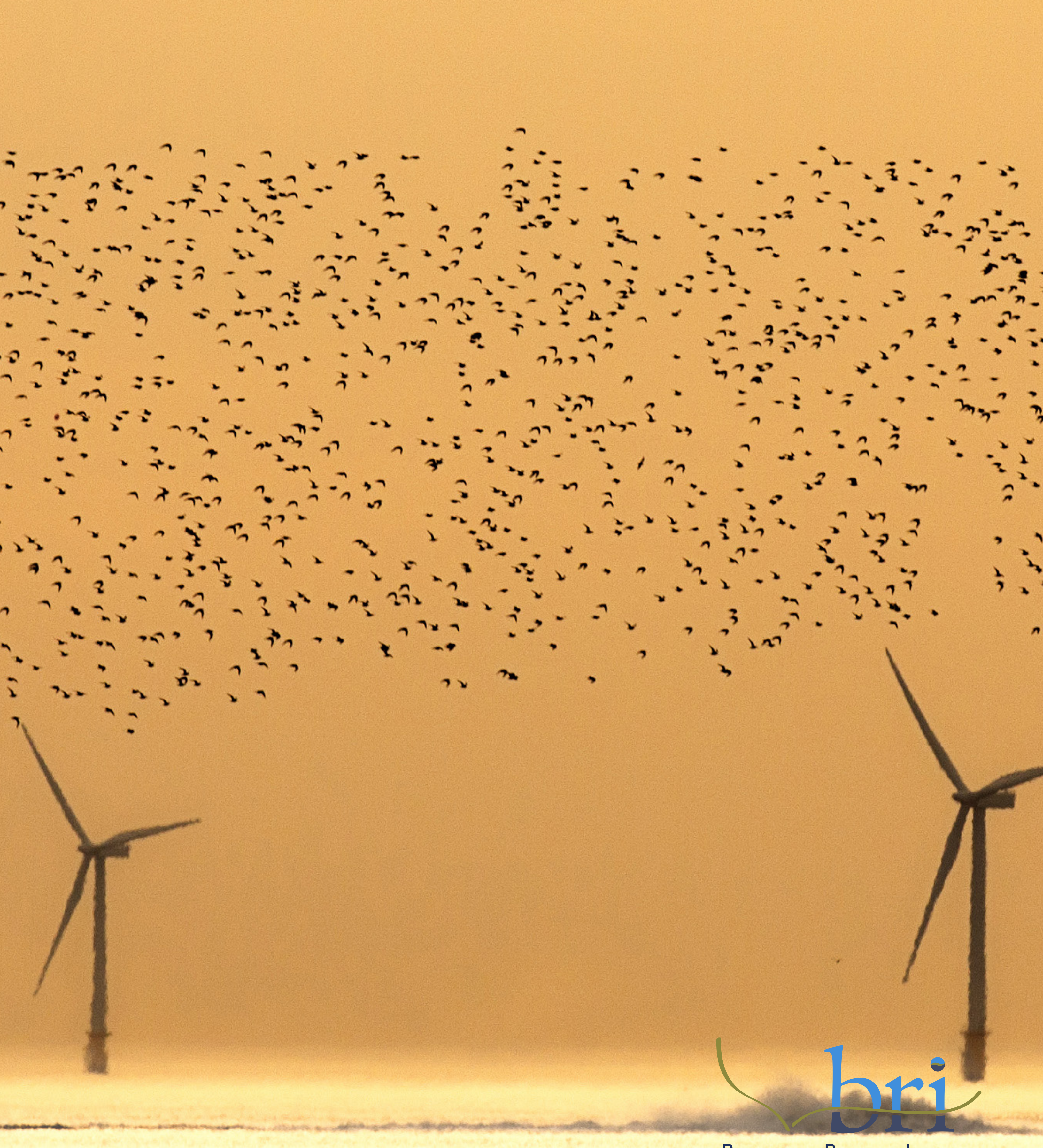
Scour protection – rocks or concrete mats placed around foundations of underwater structures to prevent softer sediments from being eroded or moved by water currents

Geophysical surveys – exploratory surveys that use reflected sound waves to assess the ocean bottom or subsurface sediments, usually for mineral exploration or to assess a prospective construction site

Sonar – the emission and detection of sound waves underwater, used to navigate or detect objects

Sound – a pressure wave that passes through air or water and is defined by its frequency (pitch), intensity (loudness), and duration

Stressors – physical, chemical, or biological factors that impact the health and productivity of a species or ecosystem



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