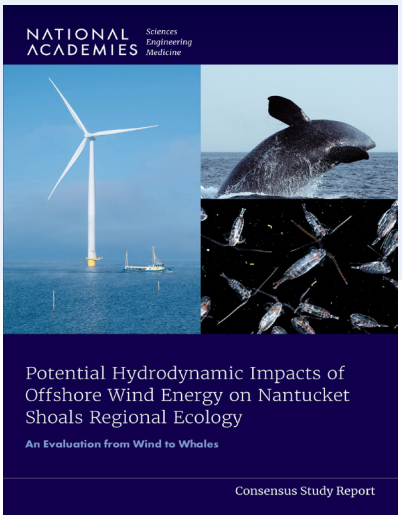
Potential Hydrodynamic Impacts of Offshore Wind Energy on Nantucket Shoals Regional Ecology: An Evaluation from Wind to Whales



The transition to renewable energy to reduce carbon dioxide emissions has spurred many efforts to scale up the U.S. portfolio of efficient clean energy resources, including the development of offshore wind farms. Although only two offshore wind farms were in operation in U.S. waters as of mid-2023—one offshore Virginia and one offshore Rhode Island—seven new wind farms are in various stages of design and development on the Northeast U.S. Continental Shelf. The Nantucket Shoals region off the coast of Massachusetts (see Figure 1) is one of the designated areas for wind farm development, because the area has conditions conducive to offshore wind installation and operation.

To ensure offshore wind energy installations are being planned, constructed, and developed in an environmentally responsible way, BOEM asked the National Academies to evaluate the potential for offshore wind farms in the Nantucket Shoals region to affect oceanic physical processes, and, in turn, how those hydrodynamic alterations might affect local to regional ecosystems. Of particular interest to BOEM are the potential effects of hydrodynamic changes on zooplankton, which may affect foraging for the critically endangered North Atlantic right whale (*Eubalaena glacialis*).

A DYNAMIC AND EVOLVING OCEANOGRAPHIC REGIME

The hydrodynamics of the Nantucket Shoals region are driven by complex interactions among such factors as shelf-break processes, seasonal and interannual variability, tides, and region-specific processes shown in Figure 2. Major oceanographic changes have occurred in the region over the past 25 years, including warming of surface and bottom water and

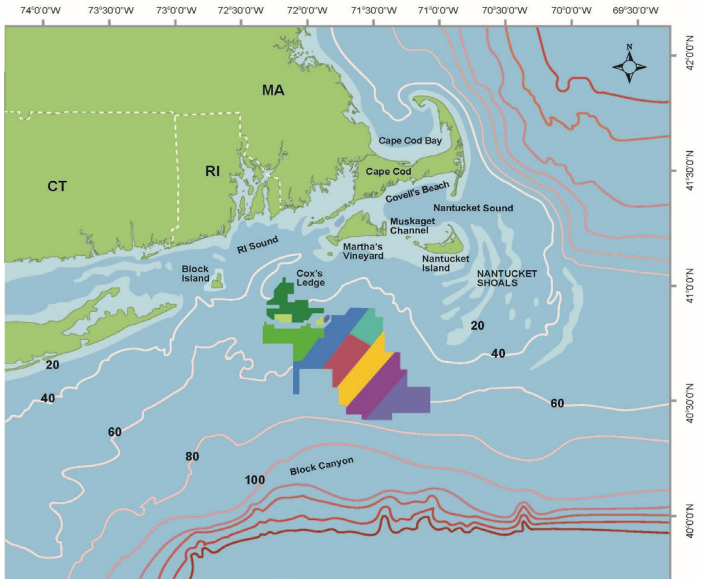


FIGURE 1: Map of the wind farm lease areas (color coded areas) in the Nantucket Shoals region.

increased frequency of Gulf Stream warm core rings that affect the oceanography of the region. Such changes can also affect phytoplankton productivity and the zooplankton that feed on them.

UNDERSTANDING POTENTIAL HYDRODYNAMIC EFFECTS

A single offshore wind turbine can alter local hydrodynamics by interrupting circulation processes through a wake effect and induce turbulence in the water column surrounding and downstream of the turbine supporting structure, the pile (Figure 3). When considering arrays of turbines in an offshore wind farm or multiple adjacent wind farms, these effects become more complex with implications for both local and regional circulation.

Knowledge of the effects of offshore wind turbine structures on hydrodynamics is limited and primarily based on modeling studies in the North Sea that have not been validated by observations. For a hydrodynamic model to be suitable for the Nantucket Shoals region, the region's key processes shown in Figure 2 should be included. In addition, most of the observational and modeling studies to date have focused on wind speed reductions at the height of the turbine and not at the sea surface where the effects of ocean surface roughness on wind stress reductions is poorly understood.

Given the limited studies to date, hydrodynamic effects of turbines will be difficult to isolate from the much larger variability introduced by natural and other anthropogenic sources (including climate change).

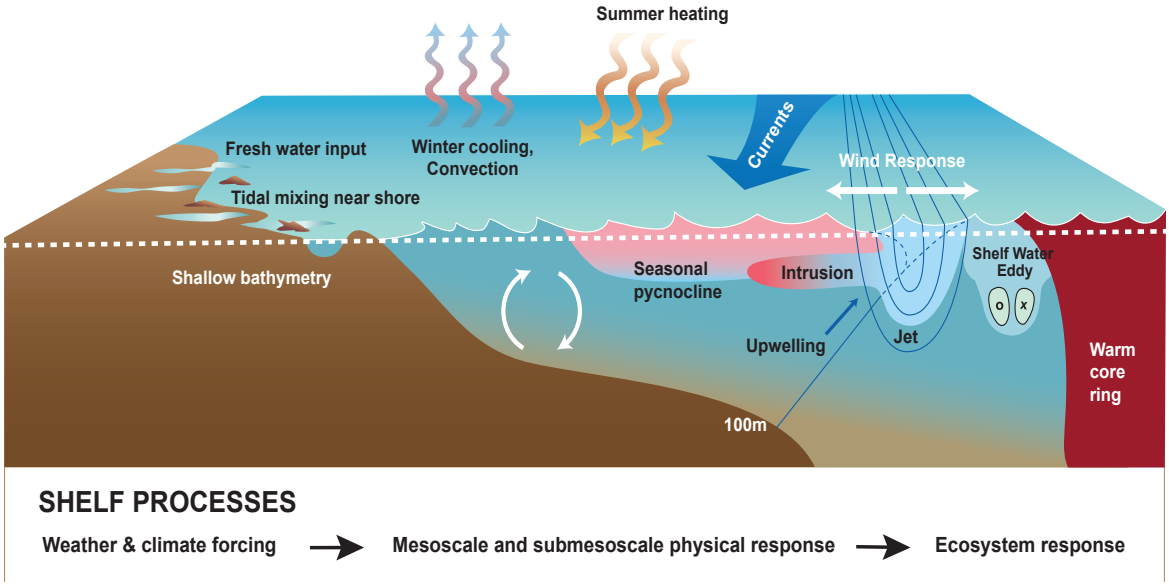


FIGURE 2: Schematic of shelf processes in the Nantucket Shoals region. SOURCE: Adapted from Gawarkiewicz and Plueddemann, 2020.

Recommendation: The Bureau of Ocean Energy Management, National Oceanic Atmospheric Administration, and others should promote, and where possible require, observational studies during all phases of wind energy development—surveying, construction, operation, and decommissioning—that target processes at the relevant turbine to wind farm scales to isolate, quantify, and characterize the hydrodynamic effects. Studies at Block Island, Dominion, Vineyard Wind I, and South Fork Wind should be considered as case study sites given their varying numbers of turbines, types of foundation, and sizes and spacing of turbines.

Recommendation: The Bureau of Ocean Energy Management, National Oceanic Atmospheric Administration, and others should require model validation studies to determine the capability and appropriateness of a particular model to simulate key baseline hydrodynamic processes relevant at turbine, wind farm, and/or regional scales.

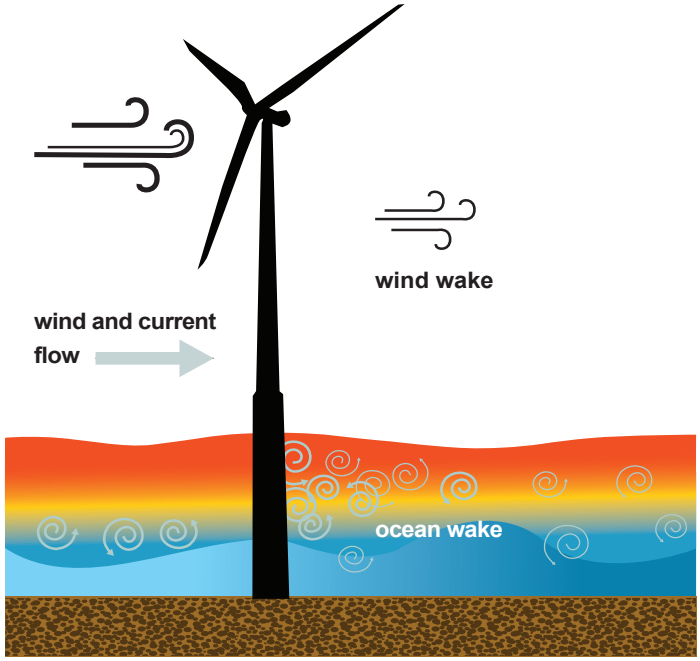


FIGURE 3: Schematic of the effects of an individual turbine on local hydrodynamics. As the wind blows across a turbine or wind farm, wind energy is extracted, thus creating a wind wake behind the turbine and reducing wind-driven circulation in the upper ocean. Additionally, the turbine structure in the water column causes an ocean wake, meaning the water becomes more turbulent behind the turbine.

POTENTIAL IMPACTS TO RIGHT WHALE PREY

Right whales have been frequently observed feeding in the Nantucket Shoals region and other areas of high productivity in Southern New England, for example, Cape Cod Bay, which is likely due to the high concentrations in winter through spring of the zooplankton that are its primary prey—the copepod *Calanus finmarchicus*. Successful foraging depends on copepods being found in sufficient densities and at appropriate depths, and as such right whales are sensitive to disturbances of their prey in the water column.

The paucity of observations and uncertainty of the modeled hydrodynamic effects make it difficult to assess the ecological impacts of offshore wind farms, particularly considering the scale of both natural and human-caused variability in the Nantucket Shoals region. Hydrodynamic mechanisms of wind energy could support any of three possibilities: (1) turbines could cause an increase in zooplankton productivity and/or aggregation of zooplankton into high-density patches to support right whale foraging and increase right whale use of this habitat; (2) turbines may decrease zooplankton productivity and/or reduce the potential for high-density aggregations, thus potentially reducing foraging opportunities for right whales in the region; or (3) wind farm development may have no appreciable impact on right whale foraging dynamics.

Studies to date do not have the spatial and temporal coverage at the proposed wind energy lease sites to adequately capture broad-scale right whale use of the Nantucket Shoals region and potential impacts from offshore wind farms. Additionally, there are gaps in understanding foraging by right whales in the region, including the basic question of which zooplankton taxa right whales are feeding on and how this prey changes seasonally. Models are needed that can effectively incorporate the supply of zooplankton, their

behavior, and the physical oceanographic processes that aggregate zooplankton in the Nantucket Shoals region.

Recommendation: The Bureau of Ocean Energy Management, National Oceanic Atmospheric Administration, and others should support, and where possible require, the collection of oceanographic and ecological observations through robust integrated monitoring programs within the Nantucket Shoals region and in the region surrounding wind energy areas before and during all phases of wind energy development: surveying, construction, operation, and decommissioning. This is especially important as right whale use of the Nantucket Shoals region continues to evolve due to oceanographic changes and/or the activities and conditions relevant to offshore wind farms.

Recommendation: The Bureau of Ocean Energy Management, National Oceanic Atmospheric Administration, and others should support, and where possible require, oceanographic and ecological modeling of the Nantucket Shoals region before and during all phases of wind energy development: surveying, construction, operation, and decommissioning. This critical information will help guide regional policies that protect right whales and improve predictions of ecological impacts from wind development at other lease sites.

CONCLUSION

The impacts of offshore wind projects on the North Atlantic right whale and the availability of their prey in the Nantucket Shoals region will likely be difficult to distinguish from the significant impacts of climate change and other influences on the ecosystem. As planning and construction of wind farms in the Nantucket Shoals region continue, further study and monitoring of the oceanography and ecology of the area is needed to fully understand the impact of future wind farms. Advancing understanding of potential impacts is especially important as North Atlantic right whale use of the Nantucket Shoals region continues to evolve.

COMMITTEE ON EVALUATION OF HYDRODYNAMIC MODELING AND IMPLICATIONS FOR OFFSHORE WIND DEVELOPMENT: NANTUCKET SHOALS

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