SETTING A COURSE
FOR RESEARCH ON OFFSHORE WIND DEVELOPMENT IMPACTS NEAR NANTUCKET SHOALS

By Glen Gawarkiewicz

The National Academies Consensus Study Report, *Potential Hydrodynamic Impacts of Offshore Wind Energy on Nantucket Shoals Regional Ecology: An Evaluation from Wind to Whales* (NASEM, 2024), is important, timely, and succinct. During this time of political and financial uncertainty regarding the development of offshore wind, this report, summarized by Hofmann et al. (2025, in this issue), offers clear directions for the research needed to resolve significant scientific and engineering questions during a time of rapid change in the Northwest Atlantic Ocean.

The report highlights the difficulty of unraveling the impacts of offshore wind development from oceanographic variability. The Northwest Atlantic is one of the most rapidly warming regions in the world ocean (e.g., Pershing et al., 2015; Chen et al., 2020; Seidov et al., 2021), resulting in a trend of increasing stratification in the region (Harden et al., 2020). While there is a longer-term warming trend, in part relating to variability upstream (e.g., Gonçalves Neto et al., 2021), extreme events, such as marine heatwaves in the region, have resulted in large temperature anomalies over time periods from days to months. Further complicating the matter, the spatial scales of the marine heatwaves depend on whether they result from atmospheric forcing or ocean advection (e.g., Chen et al., 2014; Großelindemann et al., 2022).

Another factor that makes attributing impacts in the region complex is the manner in which Gulf Stream variability has influenced continental shelf stratification and water mass properties via increases in shelf break exchange processes. Gulf Stream meanders have increased in peak-to-trough size, and their first downstream appearance from the Cape Hatteras destabilization point first shifted west over an extended period of time (Andres, 2016) and then shifted eastward over the last several years (Sánchez-Roman et al., 2024). This increased Gulf Stream variability is likely related to a regime shift in the annual formation rate of warm core rings in the year 2000 (Gangopadhyay et al., 2019). An indication of the growing influence of Gulf Stream rings and water masses on the continental shelf in this region is the remarkable increase in frequency of mid-depth salinity maximum intrusions (Gawarkiewicz et al., 2022). These intrusions commonly occur in proximity to warm core rings (Silver et al., 2023) and bring warm salty water tens of kilometers shoreward of the shelf break and potentially into the offshore wind lease areas off Nantucket Shoals. Significantly for northern right whale prey fields, salinity profiles reveal there may be several different intrusions at different depths in the water column over the continental shelf, thus possibly diminishing the concentration within an individual intrusion layer.

The flow around offshore wind turbines is affected by preexisting continental shelf processes and in turn alters those processes. A key contribution of the Consensus Study Report is to clearly delineate the three major scales over which the effects on hydrodynamics must be considered and assessed: the individual turbine scale, the wind farm scale including all turbines in the region, and the larger regional scale over which the wind farm scale exerts an impact via advection and changes in stratification. This delineation is important as both the computational approaches and the observational tools differ among the different spatial scales. Prioritization is important, as is the linkage in understanding among the scales.

A key portion of the report is the careful evaluation and summary of numerical modeling studies that highlight the wide uncertainties regarding the impacts of turbine wakes on stratification. Most of these studies have been directed toward infrastructure in the North Sea, which exhibits considerable differences in stratification, tidal velocities, and wind forcing relative to the Nantucket Shoals region. Validation of models with careful observations is stressed and will be crucial to reducing uncertainties.

Several challenges inhibit progress over these three spatial scales. Large Eddy Simulations are needed at the individual turbine scale to parameterize mixing and the downstream evolution of turbulent wakes from the turbines. On larger scales, much of the small-scale turbulence will need to be parameterized. Progress in this specific area has been achieved by numerical modelers in Europe, and parallel efforts are needed for the Nantucket Shoals region.

A significant gap that is not addressed directly in the report is the manner in which internal waves and tides have been changing over the past decade as stratification has changed. In addition

to ambient mesoscale and submesoscale processes, the characteristics of the high frequency processes have likely changed even in the absence of the wind farms. Again, it will be a challenge to differentiate changes resulting from the offshore wind development and those that may have occurred as a result of changing ocean currents and stratification. There is a clear need for observations focused on high frequency processes to support the numerical modeling.

All of the knowledge generated in understanding hydrodynamic effects will also need to be applied to further understanding regional marine ecology, as the prey fields, including prey aggregation, and the roles of convergences and localized upwelling in generating observed prey concentrations must be better understood.

There are many challenges ahead, but the Consensus Study Report produced by this NASEM committee is the clearest statement possible of the path forward. This is particularly important, as the varied funding entities include federal agencies, offshore wind developers, and foundations for all of which this report provides clear guidance on research needs and directions. Given the dire need for alternative energy sources, there is an urgent need for progress. The committee should be commended for producing a clear, eminently readable report with strong recommendations. Let us hope that the resources become available to meet the challenges that they so eloquently describe.

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