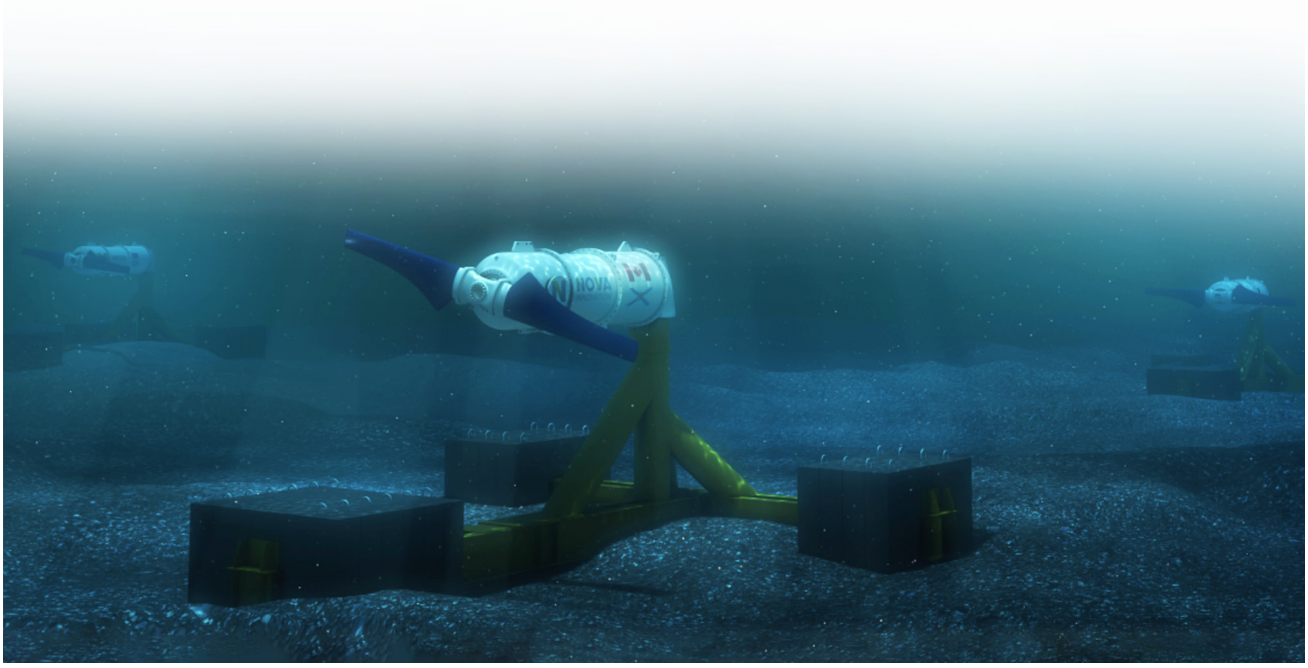
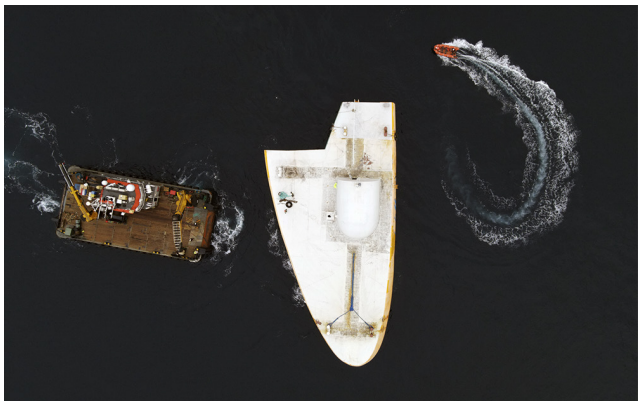
A System-Wide Effects Approach

RELEVANCE TO MARINE RENEWABLE ENERGY

To date, the focus on evaluating environmental effects has been on interactions of small numbers of marine renewable energy (MRE) devices (one to six) with the environment, including collision of animals with turbine blades, underwater noise and electromagnetic field emissions, changes in habitat, and changes in oceanographic processes. As the industry moves toward deployments of large numbers of devices (arrays), there is a need to examine potential environmental and ecological effects of MRE at a system-wide scale. This examination includes: 1) scaling the understanding of environmental effects from single devices to arrays; 2) applying an ecosystem approach to the integrated management of MRE; and 3) assessing the cumulative effects of MRE with other human-caused activities.





SCALING UP TO ARRAYS

Although our knowledge of stressor–receptor interactions (i.e., the interactions between MRE devices and associated systems, and the marine animals, habitats, and ecosystem processes) for single devices and small arrays continues to improve, remaining uncertainties complicate the task of predicting how the marine environment and ecosystems will interact with, and be affected by, large-scale arrays. These effects are unlikely to scale linearly with the number of devices, but rather scale in complex, nuanced, and site-specific ways. Investigating the potential effects of large-scale arrays requires outlining an approach and providing guidance to differentiate between unknown and actual risks of MRE development, to identify critical knowledge gaps, and to facilitate the global expansion of the MRE sector.

ECOSYSTEM APPROACH

The ecosystem approach defined by the Convention on Biological Diversity to evaluate the potential effects of human activities on the broader marine ecosystem does not currently include MRE. The approach follows an integrated strategy to manage land, water, and living resources while promoting conservation and sustainable use in an equitable manner. Scientific methods are applied to characterize the fundamental processes, functions, and interactions among organisms and their environment. Initially, the focus is on the environmental aspects of the ecosystem approach, describing how stressor–receptor interactions can lead to ecosystem-wide effects. Effects that MRE development and operation may have on local ecosystems and food webs, as well as benefits humans receive from the ecosystem (ecosystem services such as fisheries or tourism), are described within modeling frameworks. This will allow for qualitative and quantitative descriptions of the interactions between ecosystem components and MRE systems.

CUMULATIVE EFFECTS

Cumulative environmental effects arise when multiple activities occur at one location, due to sequential or overlapping human activities. The most complicated cumulative effects arise from combinations of both direct and indirect effects of the many activities caused by a variety of uses of the ocean, such as shipping, recreation, fishing, energy extraction, and others. The addition of MRE in the same areas as other anthropogenic activities may cause unforeseen environmental interactions. The understanding of environmental effects of MRE has matured to a point where there is sufficient information to begin assessing the cumulative effects of MRE development with other activities. It is necessary to develop methods for measuring the cumulative effects of MRE with other uses, and to begin to understand those effects for future sustainable management of marine resources.

RECOMMENDATIONS

Projections of potential future effects and the state of the environment into which MRE will be developed will assist planners, funders of projects, and decision-makers in determining their feasibility, smoothing the way for large-scale array deployment. This system-wide approach lays out a pathway to expand the understanding of the environmental and ecological effects of MRE development across the appropriate spatial and temporal scales, based on existing research, leveraging information on MRE devices, and highlighting gaps in scientific knowledge. This approach helps identify the main knowledge gaps, limitations, and future research needs, working toward a robust scientific framework to increase our understanding of the environmental effects of MRE development at larger spatial, temporal, and technological scales.

OES-Environmental 2024 State of the Science report and executive summary available at: *https://tethys.pnnl.gov/publications/state-of-the-science-2024*

Go to *https://tethys.pnnl.gov* for a collection of papers, reports, presentations, and other media about environmental effects of MRE.

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