2016 State of the Science Report Environmental Effects of Marine Renewable Energy Development around the World – Annex IV (Phase 2) Final Report

Public Review Draft

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Executive Summary

This report summarizes the state of the science of interactions and effects of marine renewable energy (MRE) devices on the marine environment, the animals that live there, and the habitats that support them. This report serves an update and a complement to the 2013 Annex IV report that can be found at http://tethys.pnnl.gov/publications/final-annex-iv-report-2013.

MRE development worldwide is still in the early stages of development, deployment, and commercialization. While MRE devices include those aimed at harvesting tides, waves, and ocean currents, as well as temperature and salinity differentials in seawater, the majority of environmental studies have focused on tidal turbines and wave energy converters (WECs), with some emphasis on ocean current and river turbines. This report considers turbines and WECs only.

This report was produced by the Annex IV Initiative, under the Ocean Energy Systems (OES) collaboration. Thirteen OES countries have joined together to assess the potential environmental effects of MRE development, and to learn collectively how to address potential effects that hamper siting and consenting/permitting of devices, to facilitate the establishment of the MRE industry.

The information gathered and analyzed for this report can help inform regulatory and research investigations of potential risks to marine animals and habitats from tidal and wave installations, and can assist MRE developers in developing engineering, siting, operational strategies, and monitoring options for projects that minimize encounters with marine animals and/or diminish the effects if such encounters occur. Used in conjunction with site-specific knowledge, the information from this report may simplify and shorten the time to permit (consent) deployment of single and multiple device arrays. The information brought together for analysis represents readily available, reliable information about environmental interactions with MRE devices; however, the analysis and conclusions drawn are not meant to take the place of site-specific analyses and studies, or to direct permitting (consenting) actions or siting considerations in specific locations.

Summary of Potential Environmental Interactions Associated with the Deployment of Marine Renewable Energy Devices

In a new industry like MRE, there may be interactions between devices and marine animals or habitats that regulators or stakeholders perceive as risky. In many instances, this perception of risk is due to the high degree of uncertainty that results from a paucity of data collected in the ocean. However, the possibility of real risk to marine animals or habitats cannot be discounted; the lack of data continues to confound our ability to differentiate between real and perceived risks.

Ultimately, risk will be governed by a variety of factors that include attributes of a particular device (static or dynamic), the type of device (wave or tidal), and the spatial scale of a particular installation (single or arrays). As the MRE industry continues to develop, it is important to acknowledge all of the potential mechanisms of harm these technologies may pose to the marine environment, although many of the perceived risks are likely to be small and easily avoided or mitigated. Additional strategic research investments will likely help to minimize uncertainty and elucidate actual risk. Most interactions and associated risks from single devices are unlikely to harm the marine environment until larger arrays are deployed; such arrays may require monitoring and strategic research to prepare for the commercial development of the industry.

Studies to date have shown that most of the perceived risk to animals from MRE devices is due to uncertainty about the interactions because of the lack of definitive data. While it is possible that some real risks to marine animals and habitats from MRE devices will remain after definitive data are collected, at this point in time, the uncertainties are driving most of the perception of risk and consequent challenges to permitting/consenting commercial-scale development.

Benefits of Marine Energy

The push for MRE development around the world stems from interest in developing locally derived secure energy sources that have the potential to combat the effects of climate change such as ocean acidification and increasing ocean temperatures. Deleterious effects of climate change are already affecting many marine and coastal resources, and will continue to affect the health, reproduction capabilities, and biodiversity of populations of fish, shellfish, marine mammals, and birds, and other living organisms. Similarly, climate change effects will erode the beneficial human uses we derive from the harvest and aquaculture of seafood organisms, as well as degrade coastal habitats that provide erosion and storm protection. Although laws and regulations in many countries do not explicitly allow for calculation of these beneficial uses by MRE devices as offsets for potential deleterious effects, the net benefits of MRE generation should be viewed as combatting climate change.

Collision Risk for Animals around Tidal Turbines

The potential for marine animals to collide with the moving parts of tidal devices is a primary concern for consenting/permitting and licensing of tidal developments. Where proposed tidal energy projects overlap with the habitat of protected species there are concerns that collisions could lead to injury and mortality of individuals, and affect the long-term status of the population concerned.

Marine mammals, fish, and seabirds are of greatest concern for collision, however no collisions have been observed around single turbines or small arrays to date. Studies have focused on observing the behavior of animals around turbines as a way to understand how mechanisms leading to collisions might occur. However, observing collision and animal behavior around turbines is hampered by a lack of appropriate instruments and challenging given conditions for underwater observations using acoustic or optical instruments.

Modeling efforts to estimate potential collisions with turbines provide some insight for worst-case scenarios, but need validation from the field. Researchers are also examining animal behavior around turbines including evasion, avoidance, and attraction; direct observation of animal movements and behavior in the vicinity of devices is needed to inform evaluations of risk and impacts, and to answer stakeholder and regulator questions.

Risk to Marine Animals from Underwater Sound Generated by Wave and Tidal Devices

Animals use sound in marine environments for communication, social interaction, orientation, predation, and evasion. The extent to which marine animals detect and emit sound varies by frequency and amplitude. The addition of anthropogenic noise sources from operational wave and tidal devices may induce behavioral changes, especially for organisms perceived to be at particular risk from increased noise: marine mammals, fish, diving birds, possibly sea turtles, and some invertebrates. Physical impacts may include temporary or permanent reduction in hearing ability, damage to non-auditory tissues, irregular gas bubble formation in the tissues of fish and marine mammals, and neurotrauma. Behavioral changes may also occur, such as avoidance of or attraction to the source, as well as masking—interference with communication, navigation, and detection of prey.

Measuring the sound from an operational WEC or tidal turbine is becoming more routine, although measuring low-frequency sounds that may be in the hearing range of large whales continues to be challenging. Observations of animals reacting to those sounds are even more difficult to obtain. Studies to date suggest organisms are unlikely to experience severe injury or mortality during construction and operation, but more information is needed to determine whether physical injury and behavioral changes caused by installation noise will be harmful. Most sound measurements from MRE devices have been gathered for single devices; although we can bound the likely acoustic outputs from the cumulative impacts of arrays, few field measurements have been made to date.

Changes in Physical Systems: Energy Removal and Changes in Flow

In marine environments, physical systems act as drivers for the sustainability and health of organisms. The installation of MRE devices may affect the system by changing natural flow patterns around devices, which can alter sediment distribution and transport. In addition, energy removal (along an export cable) may change the operation of a waterbody. A small number of MRE devices will not create measurable changes, but large commercial arrays might alter the system over time.

There are few field studies of energy removal and changes in flow caused by MRE devices. Many numerical models have been developed and applied to the problem, although most models have focused on optimizing power generation. Fewer models have focused on environmental concerns like changes in water circulation, sediment transport, and water quality. All the models that examine potential effects on the environment need field data to validate the conclusions, which continues to be a limitation.

Effects of EMF on Marine Animals from Electrical Cables and Marine Energy Devices

Electromagnetic fields (EMFs) occur naturally in the marine environment, while anthropogenic activities may create altered or additional sources of EMF, including those from MRE export cables. Cables are commonly buried or lying on the seabed, while inter-device cables may be suspended in the water column.

Evaluating the emissions from cables and energized devices requires measurements of the magnetic field and the induced electrical field. Laboratory and field studies examine the effects these emissions may have on marine animals, including certain electro- and magnetosensitive species of fish, invertebrates, and possibly sea turtles. Most studies have focused on the behavioral responses by animals to the EMFs including the potential for a barrier effect that might keep animals from important habitats, slowing of growth or development in larval animals, and behavior changes that might limit feeding. To date there has been no evidence to show that EMFs at the levels expected from MRE devices will cause an effect (whether negative or positive) on any species.

Changes to Habitats Caused by MRE Devices: Benthic Habitats and Reefing Patterns

The installation of MRE devices alters benthic (bottom) habitats by the addition of gravity foundations, piles, or anchors, as well as the sweep of mooring lines, cables, and mechanical moving parts. Similarly, the presence of MRE devices on the seafloor or suspended in the water column may attract fish and benthic organisms, allowing them to reef around the device, which may change their behavior, location, and perhaps have a population effect.

Most evidence of changes in benthic habitats are related to offshore wind installations, which may provide some insight into changes expected from MRE devices. Changes are not expected to be widespread or to affect benthic habitats differently than other marine industries that place structures in new areas of the ocean.

Effects that MRE devices have on reefing fish are not known, and are expected to be very similar to those of other marine industries, including the installation of artificial reefs, which have not been shown to have deleterious effects on fish populations. It is possible that MRE devices will increase the density of certain fish species locally.

Marine Spatial Planning and Marine Renewable Energy

Marine spatial planning (MSP) involves an approach to planning and managing sea uses and users to support sustainable development of marine areas. The rationale for MSP is to provide a stable and transparent planning system for maritime activities and users within agreed environmental limits to ensure marine ecosystems and their biodiversity remain healthy, working across multiple sectors.

Annex IV representatives were surveyed to determine the extent to which MSP processes exist in their countries. Several nations have formal MSP processes in place, others have coastal management plans that embody some of the principles of MSP, and several have no MSP in place.

Case Studies that Examine Siting and Permitting of MRE Devices

The consenting process is still regarded as a barrier for the sector to scale up and become cost-competitive with other forms of electricity generation. Uncertainties about the application of environmental legislation can prolong consenting processes, adding costs, delays, and significant uncertainty. Four case studies are presented: two tidal devices (ORPC TidGen® Power System, installed in the United States; MCT SeaGen technology installed in Northern Ireland); one WEC (WaveRoller, installed in Portugal); and one designated test site (BIMEP, in the Basque Country, Spain). The intent of the case studies is to provide insight into the various complexities associated with siting and consenting MRE projects and test sites.

Time-consuming procedures—linked to uncertainty about project impacts and the need to consult with numerous stakeholders before reaching a permitting decision—appear to be the main obstacles to consenting of ocean energy projects. Dedicated legislation does not exist or is not clear in the jurisdictions examined. However, in some cases, regulators are willing to collaborate with developers. The consenting process and the environmental monitoring requirements are costly.

Outreach efforts, perceived as being critical to working with stakeholders, promote public awareness and understanding about MRE technologies. There is also a need to improve or adapt existing legislation and guidance to facilitate licensing of MRE farms. These efforts are already under way in some nations.

Summary and Path Forward for Marine Energy Monitoring and Research

The 2016 State of the Science report summarizes and places in context information about the environmental effects of MRE development, to the extent that the information is publicly available. As single device deployments continue and development of the first commercial arrays is on the horizon, several critical interactions between MRE devices and marine animals continue to concern regulators and stakeholders: collision, underwater sound, and electromagnetic fields.

The risks associated with many interactions continue to be driven by uncertainty; these risks need to be better understood and managed, as they are for other established offshore industries. The interactions that are shown to not cause harm to the marine environment need to be "retired," allowing research and monitoring efforts to focus on the highest priority interactions. All of these risks can be parsed into three groups: 1) low-risk interactions that have been discounted or retired from ongoing monitoring; 2) interactions that have a high level of uncertainty and require further investigation; and 3) interactions that are known to be high risk to the marine environment and that will require mitigation through improved siting, improved design or operation of the devices, and perhaps an adaptive management approach, prior to scaling up to arrays. Eventually all interactions should be retired or mitigated through a range of actions including avoidance and minimization.

The interactions among marine animals/habitats and MRE devices that the regulatory community feels are important can be approached through three strategies:

1. Certain interactions can be effectively monitored now with existing instruments, platforms, and technologies, although improvements in the instrumentation and data management could make monitoring more efficient.
2. Other interactions require targeted strategic research efforts immediately in order to understand the risk of the interaction, and to decrease the costs and years of monitoring over the life of a project.
3. Certain interactions can only be advanced with strategic research investments, because there is no viable path forward for monitoring at this time.

Researchers, regulators, and developers have an opportunity to identify and hone strategic research investments that could inform the stressor-receptor interactions that are highly uncertain, allowing for streamlined pathways to siting and consenting/permitting, as well as lowering ongoing post-installation monitoring costs to supportable levels to move the industry forward. A framework for determining those strategic research investments is included in the report.