A SNAPSHOT OF RISK FOR ENVIRONMENTAL EFFECTS OF MARINE RENEWABLE ENERGY DEVELOPMENT

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BACKGROUND

With only a few wave and tidal devices in the water and no long-term post-installation data sets available, there continue to be uncertainties around risks to marine animals and habitats from the deployment and operation of marine renewable energy (MRE) systems [1], [2]. Based on these uncertainties and lack of familiarity with MRE devices, regulators and stakeholders continue to perceive a wide array of potential environmental interactions as risky; and they continue to require extensive monitoring programs to permit or license a project. The financial burden of monitoring is difficult for MRE developers to support, and it is not clear whether the planned data collection efforts are necessarily aimed at the most important interactions that present the highest levels of risk to the marine environment. It appears that an important pathway toward commercial development of MRE projects should include a delineation and evaluation of these risks.

CURRENT STATE OF KNOWLEDGE

Recent reviews of existing information, including the 2016 State of the Science report [1], have summarized the key risk areas that continue to slow siting and permitting of MRE devices and arrays. The greatest concerns expressed by regulators and stakeholders are associated with the following:

- potential collision of marine animals with turbine blades;
- effects of underwater noise from turbines and wave energy converters (WECs) on marine animal behavior and health; and
- potential effects of electromagnetic fields (EMFs) from cables and energized devices on certain marine species.

To date there have been no observations of marine mammals or seabirds colliding with turbines, and fish interactions have not been shown to be harmful. The amplitude and frequency of sound from WECs and turbines do not appear to be sufficient to badly disturb marine mammals or fish, although animal behavior studies in response to these sounds are virtually nonexistent. Effects of EMFs on sensitive species do not appear to prevent crabs and other invertebrates from reaching their preferred habitats or affect their distribution patterns based on observational studies. However, specific data gaps remain for these and other interactions.

EVALUATING RISKS OF MRE DEVELOPMENT

Risks due to uncertainty may be reduced and perhaps retired with the collection of definitive data, while actual risks to animals and habitats can be avoided or mitigated. Interactions that continue to be uncertain can then become the focus of proportional monitoring programs, whose goal can be better understanding and minimizing those risks.

We propose a strategy for reaching common understanding of the status of risk for major interactions between MRE development and the marine environment, through the development of a set of dashboards that visually indicate the level of risk for the following:

- noise;
- EMFs;
- removal of energy and physical changes;
- changes in benthic habitats;

- collision;
- entrapment or entanglement in mooring lines; and
- attraction of organisms (e.g., artificial reef).

Developing Risk Assessment Dashboards

We have developed a series of dashboards to visually display the level of risk for major interactions between MRE devices and the marine environment. The dashboards are patterned after old-fashioned car dials and display the risks as they are currently understood, as informed by modeling, monitoring, and research results (Figures 1–7). The lowest levels of risk are shown as green, medium risks as yellow, and the highest risks as red.

The purpose of the dashboards is to allow the MRE community to gage the level of uncertainty and risk for key interactions, as we know them at this time, and to reflect the results of ongoing investigations as we move forward. We foresee updating the dials on the dashboards as research and monitoring results inform the risks represented by the dashboard dials.

We developed the dashboards for initial release at an environmental regulatory workshop, held in conjunction with the 11th Annual Ocean Renewable Energy Conference in Portland, Oregon, September 21, 2016. We debuted the dashboard approach for the regulators and developers attending the workshop, and laid out the current understanding of levels of perceived risk.

We also proposed four types of actions that could be pursued to decrease the existing level of risk for each interaction, also colloquially known as "moving toward green." The four types of actions fall into the following categories:

- increased sharing of existing information,
- improved modeling of interactions,
- monitoring data needed to verify findings, and
- new research needed.

Determining the Risk Level for Each Interaction

The perceived risk levels demonstrated by each of the dashboards (Figures 1–7) are based on informed opinion of researchers, regulators, and applicants around the world. Depending heavily on the recent comprehensive assessment of risk from MRE development [1], as influenced by input from the participants at workshop held during the the Oregon Wave Energy Trust (OWET) conference, the dial location was set for each dashboard, for the reasons identified in the paragraphs accompanying the figures below.

The following legend applies to the bar charts found in Figures 1 through 7:

- Increased sharing of existing information
- Improved modeling of interaction
- Monitoring data needed to verify findings
- New research needed.

Acoustic Output (Noise) Effects on Marine Animals

The ability to measure the acoustic output of tidal and wave devices has been fairly well developed, and the output of multiple devices in an array can be modeled, but very little is known about how marine mammals, some fish, and sea turtles are likely to react to the sound [1]. This uncertainty places the risk level at moderate to high, or yellow (Figure 1).

FIGURE 1. DASHBOARD OF ACOUSTIC OUTPUT (NOISE) EFFECTS ON MARINE ANIMALS

Effects of Electromagnetic Fields on Marine Animals

The effects of underwater cables in the ocean from telecom and electrical power distribution do not suggest that marine animals are likely to be harmed by the levels of EMF from MRE devices. Field experiments [3] [4] and laboratory studies [5] support this theory, although questions remain about effects on specific benthic and pelagic animals in the vicinity of high-power export cables that may not be completely resolved until higher levels of MRE deployment take place. This places the risk level at moderately low, or green (Figure 2).

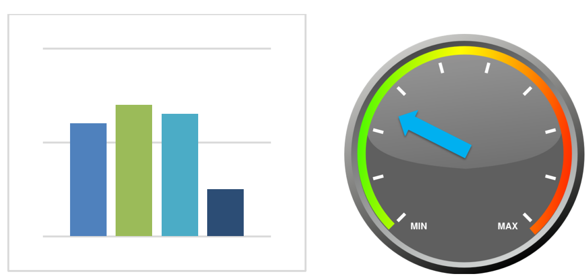

FIGURE 2. EFFECTS OF ELECTROMAGNETIC FIELDS ON MARINE ANIMALS

Physical Changes – Energy Removal and Changes in Flow

Modeling studies of energy removal and changes in flow indicate that small numbers of tidal or wave devices will have no measureable effect on the environment [6]. In the future, with the deployment of large arrays, this outcome will need to be verified with the concomitant large removal of energy and changes in flow. These findings indicate that this is a very low risk, or green (Figure 3).

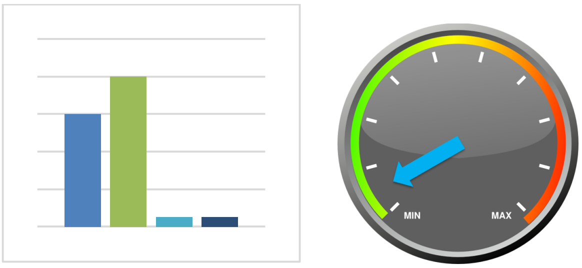

FIGURE 3. PHYSICAL CHANGES (ENERGY REMOVAL AND CHANGES IN FLOW)

Changes in Habitats/Attraction to artificial reefs

MRE devices present very few novel challenges to the marine environment that have not been observed for other coastal and marine industries and development [7]. The small footprint of wave and tidal devices, when appropriately sited, will be very small in large stretches of uniform habitat, putting very small amounts of habitat and benthic animals at risk. This results in a very low overall risk, showing green on the dashboard dial (Figure 4).

FIGURE 4. CHANGES IN HABITATS/ATTRACTION TO ARTIFICIAL REEFS

Collision Risk – Tidal

Collision of marine mammals, fish, sea birds, and sea turtles with rotating tidal turbine blades continues to be the highest perceived risk of tidal development [1]. Although a collision between a marine mammal, seabird, or turtle with a tidal device has never been observed, and interactions with fish have shown no adverse outcomes, this risk continues to slow permitting, requiring further inquiry and assessment. This situation results in a high perceived risk level, red on the dashboard dial (Figure 5).

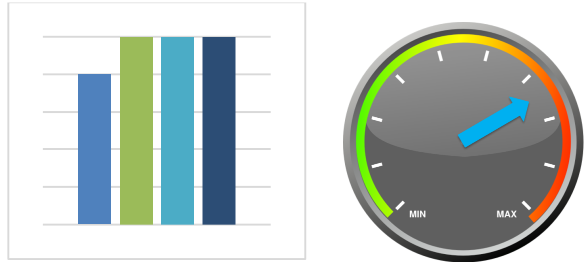

FIGURE 5. COLLISION RISK (TIDAL)

Ecological Effects of Entanglement

Concerns about the possibility of large marine mammals becoming entangled in mooring lines and draped cables from wave devices and floating tidal devices have been raised, but there is no indication of this occurring with similar lines and cables used by other industries [1]. If fishing gear were to be entangled on lines, there is a small risk that draped gear could act as derelict fishing gear, catching and killing smaller sea life. For this reason, the risk is seen as moderately low, or green on the dashboard dial (Figure 6).

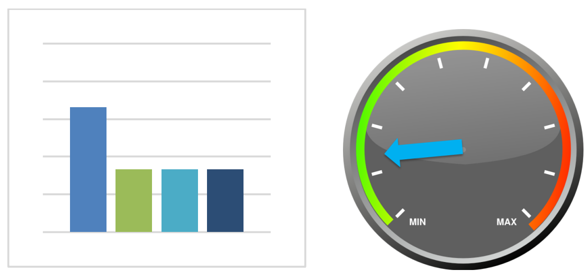

FIGURE 6. ECOLOGICAL EFFECTS OF ENTANGLEMENT

Entanglement of Fishing Gear

While the ecological risk of entanglement with mooring lines is perceived to be low, commercial fishers are concerned that these lines will entangle their gear, presenting risk to the fishing industry [8]. For this reason, the risk is considered to be moderately high, or yellow on the dial (Figure 7).

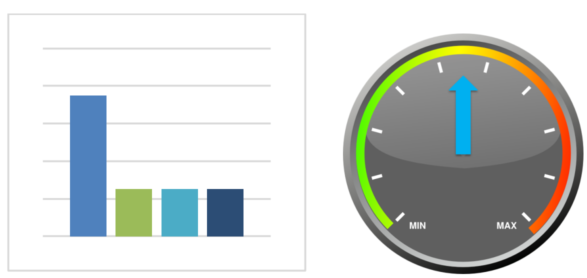

FIGURE 7. ENTANGLEMENT OF FISHING GEAR

MOVING FORWARD UNDER UNCERTAINTY

The levels of perceived risk, as visually demonstrated by the dashboard dials, can be used as benchmarks, with the goal of reducing each risk as much as possible. Using the four strategies (increased sharing of existing information; improved modeling of interactions; monitoring data needed to verify findings; and new research needed) developed in conjunction with the dashboards, the risk-reduction path forward can be delineated.

Increased Sharing of Information

Field data collection, laboratory experiments, and modeling studies of MRE devices and the marine animals and habitats with which they may interact provide insight into and information about the likely risks from small- and commercial-scale deployments. By collating, analyzing, and disseminating the information, the perceived level of risk can be better assessed, and in most cases, decreased from red or yellow on the dashboard dial toward green. Particular advancement in determining and lowering risk could be achieved for changes in habitat (Figure 4) and entanglement (Figures 6 and 7), while all other interactions would also benefit from increased sharing of information.

Improved Modeling of Interactions

As data are collected from field deployments, post-installation monitoring, and supporting laboratory field experiments, the most cost-effective means of understanding and estimating the level of risk of interactions can be gained from modeling those interactions. In particular, modeling EMFs (Figure 2), physical changes in marine systems (Figure 3), and collision risk (Figure 5) will be better informed and the perception of likely risks decreased.

Monitoring Data Needed to Verify Findings

Modeling of interactions will help to simplify and allow for increased transferability of data sets from one location to another. However, the need to collect sufficient monitoring data around deployed devices will continue, at least with early deployments of single devices and arrays, in order to validate and assure the realism of the models. Monitoring of data collection is particularly needed to decrease the perceived risk of interactions of acoustic output effects on marine animals (Figure 1) and collision risk (Figure 5).

New Research Needed

While dissemination of existing knowledge, as well as modeling of interactions and validation by monitoring data will help to elucidate and (in most cases) decrease the perceived risk of all interactions, areas of insufficient fundamental understanding of those interactions still exist. These deficits can be remedied by new research projects strategically aimed at answering the interaction questions that may differ among technologies (wave and tidal), among different device configurations, and for different animal populations. Questions of temporal and spatial scales over which effects might be felt could be answered, and the seasonality of key animal populations in relation to their vulnerability to MRE device interactions could be better determined. In particular, strategic research projects are needed to lower the perception of risks from of collision (Figure 5) and acoustic output (Figure 1).

CONCLUSIONS

Permitting processes for MRE deployment continue to be slowed and stalled in the US and abroad by perceptions of harm that may befall marine animals and habitats. We have attempted to document the perceived risk levels associated with the most important interactions, and proposed a path forward for moving many of the risk levels to lower levels, perhaps "retiring" some from the need for significant data collection and analysis efforts.

We believe that the dashboard approach and the pathways laid out can help members of the MRE community reach efficient and responsible deployment levels that will help move the US and other nations toward significant MRE contributions of reliable renewable energy. Specifically, regulators will be able to observe and provide input into the dashboard process concerning the level of risk they are comfortable with assuming as they permit installations. Using the dashboards, MRE developers will be able to estimate the concerns and level of risk that are likely to drive regulatory requirements for pre-installation assessments and post-installation monitoring of effects. The research community can use the dashboards to iterate data collection and analysis related to interactions where uncertainty and risk continue to drive permitting issues for MRE development. Taken together, these interactions will allow the community to reach consensus on strategic research agendas, estimate monitoring needs that are proportional to the risks, and move collectively toward reducing and retiring risk. This consensus will help to support commercial MRE development while protecting the natural resources of our oceans, coasts, and rivers.

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