Managing Environmental Effects to Facilitate Marine Renewable Energy Development

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Abstract— The marine renewable energy (MRE) industry is in the early stages of commercial development. In addition to the challenges of deploying and maintaining devices under harsh ocean conditions and transporting electricity to shore, concerns around potential environmental effects continue to slow permitting (consenting) processes. Regulators and stakeholders perceive a wide array of potential environmental interactions as risky and highly uncertain, and request that considerable baseline assessments and post-installation monitoring be carried out in order to permit or license a project. The MRE industry is struggling with the high cost of baseline assessments and post-installation monitoring, as well as extended timelines for obtaining permits, leading to uncertainty and risk for financing projects. As a means to mitigate this uncertainty and risk, regulators in the US have been engaged to ensure that they understand the underlying science that drives these challenges and to explore the feasibility of transferring learning and information from early MRE projects and analogous industry interactions to inform potential environmental effects and permitting for new MRE projects. The ability to use data and information from one project or location to another can aid the industry by reducing the high costs of environmental monitoring and accelerating permitting processes for future projects. This paper presents findings of a regulator survey and other engagements with regulators, provides insight into the process of data transferability, suggests a framework for data transferability and collection consistency, and details efforts to engage the research community in furthering this process.

Keywords—**Marine renewable energy; environmental effects; data transferability; survey methods; risk management.**

I. Introduction

The marine renewable energy industry (MRE) is young, with most modern wave and tidal devices designed over the past 10-12 years. As soon as deployments were proposed, stakeholders and regulators began to express concerns about potential risks to marine animals and habitats from a variety of stressors associated with moving parts, anchoring systems, and power generators associated with wave energy converters (WECs) and tidal turbines [1]. During the early years of development, a wide variety of potential risks were identified ranging from concerns about releases of chemicals from anti-fouling paints, to concerns about animals being injured by rotating tidal blades, to deleterious effects of animals being attracted to floating WECs.

The concept of examining specific stressor-receptor interactions between MRE devices and the marine environment have been widely adopted [2], where stressors are any part of the MRE system or output of the system that may cause injury or stress to the environment, while receptors are those specific species, habitats, or ecosystem processes that may be harmed. In the past decade, researchers have made progress in understanding some of these risks, based on analogues to other industries, field studies, laboratory experiments, and modelling studies [2]. By 2012 or so, it was assumed that many other risks would be resolved as arrays of WECs and turbines were deployed and monitoring studies carried out [3]. However, there are still only a few wave and tidal devices in the water and no long-term post-installation datasets available. Based on the continuing lack of monitoring data, there continue to be uncertainties around risks to marine animals and habitats from the deployment and operation of MRE systems [2] [4]. 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 require considerable monitoring in order to permit or license a project [2] [4]. The MRE industry is struggling with high costs of baseline assessments and post-installation monitoring, as well as long timelines for obtaining permits, leading to uncertainty and risk for financing projects.

In order to move towards commercial development of MRE projects, there is a need to distinguish among environmental risks and to manage them. Risks due to uncertainty can likely be reduced and perhaps retired with the collection of additional data, while actual risks to animals and habitats can be avoided or mitigated. Interactions that continue to be uncertain, yet are perceived to be potentially risky, can become the focus of proportional monitoring programs, with the goal of better understanding and minimizing those risks.

The most recent comprehensive review of existing information, the Annex IV 2016 State of the Science report, summarizes the key risk areas that continue to slow siting and permitting (consenting) of MRE devices and arrays [2]. By 2016, the greatest concerns expressed by regulators and stakeholders are associated with:

- Potential collision of marine animals with turbine blades;
- Effects of underwater noise from tidal turbines and WECs on marine animal behavior and health; and
- Potential effects of electromagnetic fields (EMF) from cables and energized devices on certain marine species.

The 2016 State of the Science report states that to date there have been no observations of marine mammals or seabirds colliding with turbines, while fish interactions have not been shown to be harmful [2]. The amplitude and frequency of sound from WECs and tidal turbines do not appear to be sufficient to significantly disturb marine mammals or fish, although animal behaviour studies in response to these sounds are virtually non-existent. Effects of EMF on sensitive species do not appear to prevent crab 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 [2].

II. Regulator Engagement

Regulators at the federal and state level in the US and other nations must satisfy legal and regulatory mandates in order to grant permission to deploy and operate MRE devices. Inherent in these laws and regulations is a concept of balancing risk to the environment, human uses of public resources, economic development, and human well-being. Many research efforts related to the potential effects of MRE development are focused on this concept of risk, and the interactions between devices and the environment most likely to cause harm, or those for which the greatest uncertainty exists [2].

A. Regulator Survey Results

In 2017, US regulators were engaged through webinars and an online survey to better understand their views on risks, conflicts, and challenges associated with permitting environmental effects of MRE devices. US federal and coastal states' regulators participated in an online survey to express their familiarity with MRE technologies, their perceptions of the most important environmental challenges, and their thoughts on the best approach to MRE development and data transferability between projects.

Of the 35 responses, 15 participants worked in federal agencies and 20 worked for state agencies; not all participants answered every question. The majority of participants (60% federal and 65% state) had previously participated in permitting at least one MRE project, although almost all were associated with single devices.

1) Familiarity with MRE Technologies: The regulators were not very familiar with different wave and tidal technologies. Overall, the federal participants were more familiar with several common designs of WECs and tidal turbines than state participants (Fig. 1).

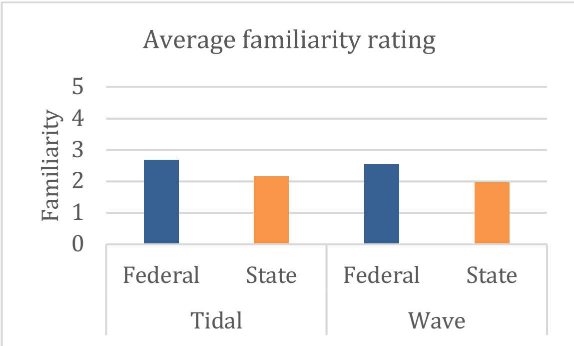

Fig. 1. Regulators' response for familiarity with WECs and tidal turbines, ranging from 1 (not familiar) to 5 (very familiar).

2) Challenges for Permitting MRE Devices: Participants were asked to rank the eight top challenges for permitting a single MRE device and permitting an array. Responses varied by federal or state regulators and by the number of devices. For single devices, the top challenge expressed by federal regulators was "effects of underwater sound emissions from devices on animals," whereas state regulators envisioned the top challenge as "benthic/habitat destruction." For arrays, both federal and state regulators listed "avoidance, attraction, and/or displacement of animals" as the top challenge for writing permits for devices.

3) Data Transferability: Participants were asked if information collected from early projects could be applied towards environmental permitting within their jurisdictions. The survey explained that this "data transferability" might involve raw or quality assured data but were more likely to take the form of analysed or synthesized datasets, reports, and similar analyses. The survey results indicated that such data transferability should be further explored, with 25% of state regulators and 36% of federal regulators answering that data "absolutely" should be transferred (Fig. 2).

4) Survey Conclusions: Overall, the survey results showed that specific concerns about risks to marine animals and habitats from MRE development are related to the jurisdiction of individual regulators (for the US: federal versus state), and by their degree of knowledge about specific types of WECs or tidal turbines. Based on these survey results, it appears that progress towards better understanding and acceptance of risks associated with MRE permitting can be made by: 1) active and ongoing dissemination of information on MRE devices and their interactions with the marine environment; 2) conducting new research to answer outstanding effects questions; and 3) applying data collected from early projects to planning and permitting future projects.

III. Data Transferability and Collection Consistency

Regulators require environmental assessment and monitoring information to support their analyses to describe, permit, and manage the environmental risks associated with MRE technologies and the new uses of ocean space that they represent. However, regulators and stakeholders currently lack access to synthesized and contextualized data emerging from early MRE projects and there is no mechanism to apply data and information across geographically distinct projects. This leads to each individual project bearing the full burden of information requirements on a site-by-site basis. In addition, monitoring data around early MRE devices and associated research studies are collected using many different methods, instruments, and measurement scales.

A possible solution to these challenges is "data transferability." In this context data transferability has been defined as using data from an early stage MRE project or analogous industry to be "transferred" to inform potential environmental effects and permitting for a new MRE project. Such data can include raw or quality-controlled data, but more likely it will be analysed or synthesized data and information, in the form of reports, research studies, or other media.

A literature review was conducted to understand how challenges related to data transferability and data collection consistency have been addressed in other industries. Insights and potential data transferability frameworks, models, and approaches were investigated and the limits of data collection consistency as an important aspect of supporting data transferability were examined. The literature came from a wide range of fields including economics, transportation, ecology, and land system science.

Studies that focused on data needs and best practices related to data transferability stressed the importance of developing transferability guidelines to support the application or transfer of data from one project to another [5]. The studies of data transferability contained a common thread of the importance of data collection consistency if one wishes to transfer data. Differing data collection methods that produce incompatible data can greatly affect the transferability of data [6], as can the spatial scale, temporal scale, definition, and context of the data collected [5] [6]. In

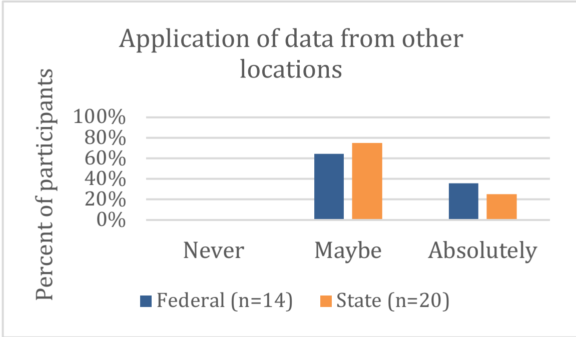

Fig. 2. Regulators' response for use of data collected from one location for environmental permitting in their jurisdiction

terms of transferring data from early MRE projects to inform future projects, it is important to ensure that the data were collected with the same purpose and target similar questions. Developing common standards for data collection can aid in the comparability of findings and data transferability [5]. The first complete monitoring datasets from commercial arrays are just becoming available. There is an opportunity to capture those data in an organized manner, understand and document the methodologies with which the data were collected, and widely disseminate the associated metadata. Providing this record and availability of datasets has the potential to support data transferability.

As the MRE industry matures, the ability to readily transfer research and monitoring results, data, study designs, data collection methods, and best practices among projects and across jurisdictional boundaries can help reduce risks to the industry and the environment. Many developers may be reluctant to share environmental data as they see them as proprietary or representing a financial advantage over their competitors. However, if the information contained in monitoring datasets and research studies can be made readily available, regulators may require less baseline and post-installation data collection, leading to cost reductions for project developers and ultimately to more efficient and shorter permitting processes, further decreasing financial risk for MRE project development.

IV. Data Transferability Framework

The elements of data transferability and collection consistency have been applied to a framework for furthering the ability to use MRE environmental data collected from early projects to future projects. Drawing from available studies and the results of the regulator survey, five specific stressors were chosen as being of continuing importance to MRE permitting:

- Collision risk (specific to tidal turbines)
- Underwater noise from devices (wave and tidal)
- Electromagnetic fields (wave and tidal)
- Changes in benthic and pelagic habitats (wave and tidal)
- Changes in physical systems due to changes in water circulation (tidal) or changes in wave heights (wave).

A. Marine Renewable Energy Archetypes

Based on the literature review, certain similarities and criteria among the data should be met in order to use data collected from early MRE projects to inform future projects. Inherent to this framework is the need to assure a level of consistency with which the data were collected from projects to be compared.

The most promising transferability methodology and framework gleaned from the literature is presented by Václavík et al. [7] for sustainable land management. The authors' concept of defining a project "archetype" based on a variety of indicators can be applied to other place-based studies, including MRE studies. By adopting the concept of an "MRE project archetype" (MREPA) a combination of stressors, site conditions, MRE technologies, and receptors can be used to describe a dataset (Fig. 3). By generating MREPAs it will be possible to compare datasets from early projects with those of datasets expected for future projects.

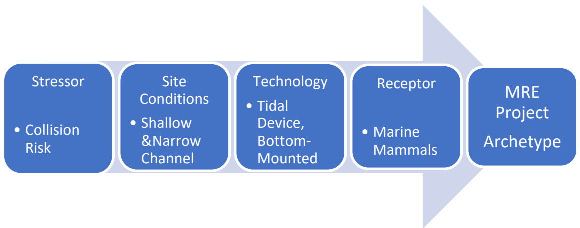

Fig. 3. Path to identifying marine renewable energy PROJECT archetypes. This example uses collision risk for marine mammals around tidal turbines.

For each of the five stressors identified, a matrix was developed that considers all likely combinations of site conditions, technology categories, and susceptible receptors. An example of the matrix for collision risk is shown in Table I. For this stressor, a total of 22 possible MREPAs can be generated. Similar matrices for underwater noise, EMF, changes in habitats, and changes in physical systems will generate 8, 10, 9, and 4 MREPAs, respectively, for a total of 53 possible MREPAs.

B. Applying the Framework

The purpose of applying the data transferability framework is to classify projects by archetype to enable discovery of existing datasets that are comparable and to inform the potential risks of future projects. Once comparable datasets have been discovered and reviewed, there is a strong potential that trends and conclusions about specific interactions and risks from the existing datasets can inform future projects, resulting in a decrease in need for site-specific data collection, and more efficient permitting/consenting.

A series of steps have been devised to apply the framework:

1. Characterize the MREPA dataset for a future project (such as one that might be presented to a regulator);
2. Discover datasets from early projects with the same MREPA;
3. Evaluate the transferability potential of information from existing projects to the future project, where the two projects *must share the same MREPA*;
4. The degree of transferability can be evaluated by examining the receptor species, specific technology types, wave or tidal resource, and geographical proximity of the projects to one another, with the necessity of matching all features from existing datasets to those of future projects, decreasing with each step (Fig. 4).

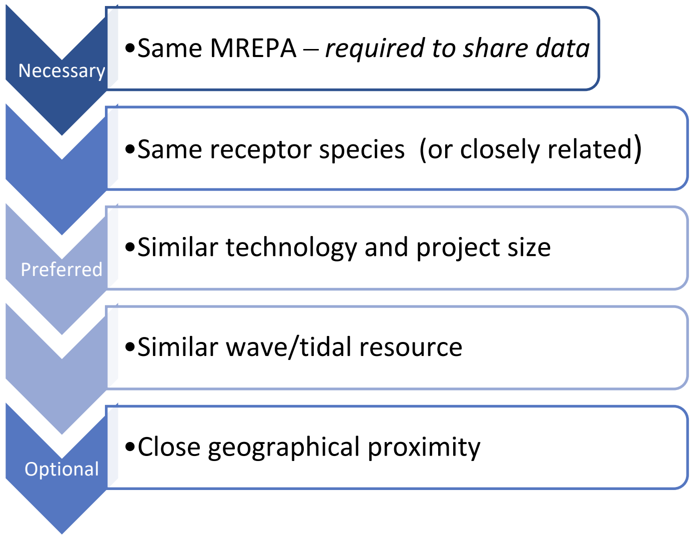

Fig. 4. Evaluation Hierarchy for transferability potential of data.

C. Best Management Practices and Implementation

Best Management Practices (BMPs) has been used to describe acceptable practices that could be implemented to protect water quality as well as associated resources and habitats [8]. BMPs are intended to be practices or procedures that are qualitative and flexible.

BMPs were developed to enable the Data Transferability Framework is applied consistently:

- Meet the minimum requirements (rules of transferability + MREPAs) to be considered for data transfer from one location or project to another.
- Determine likely datasets that meet data consistency needs.
- Use models in conjunction with and/or in place of datasets.
- Provide context and perspective for datasets to be transferred.

Guidelines for implementation of the BMPs are under development.

V. Outreach and Engagement

Approximately 30 US regulators were brought together in a series of focus groups to understand the challenges of interpreting data and analyses from existing MRE projects, and the limitations for transferring data to projects in their jurisdictions. The regulators were also asked to provide feedback on the data transferability framework/MREPAs.

Site Conditions *	Technology	Receptors
Shallow and Narrow Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
		Diving Birds
	Tidal Device in the Water Colum	Marine Mammals
		Fish
		Diving Birds
Deep and Wide Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
	Tidal Device in the Water Colum	Marine Mammals
		Fish
		Diving Birds
Shallow and Wide Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
		Diving Birds
	Tidal Device in the Water Colum	Marine Mammals
		Fish
		Diving Birds
Deep and Narrow Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
	Tidal Device in the Water Colum	Marine Mammals
		Fish
		Diving Birds

*Shallow channels are defined as having a depth less than 40 m. Deep channels are defined as having a depth greater than 40 m. Narrow channels are defined as having a width of less than 2 km. Wide channels are defined as having a width greater than 2 km.

TABLE I EXAMPLE OF A MARINE RENEWABLE ENERGY PROJECT ARCHETYPE MATRIX – COLLISION RISK.

A. Preliminary Results

In discussions with regulators several themes appeared. Regulators are not necessarily looking for raw data, but data that they can interpret and easily understand. For example, when shown underwater noise data most regulators had a preference for graphs of sound frequency and amplitude, rather than sound clips plotted over time. They also found it helpful to be presented video clips of the movement of MRE devices in the water, audio clips of the sound from turbines and WECs, and synthesized data and information on other stressors. Several regulators stressed the importance of using data and outcomes from analogous industries, and the difficulty that finding those data might present. Throughout the workshops, there was strong support from regulators for the data transferability framework and MREPAs concept, with many stating that they needed a method for dataset discoverability to find comparable datasets with which to inform their permitting decisions.

B. Next Steps

Following the regulator focus groups, progress on the MREPA framework will be shared with the MRE community at an international workshop to gather provide additional feedback for the MREPA framework, to review and modify proposed BMPs, and to discuss ways to implement the process.

VI. Conclusion

This paper presents findings of a survey of US regulators on their knowledge of MRE devices and their thoughts and concerns for writing permits under present levels of uncertainty. A framework for discovering and comparing datasets is proposed to support data transferability, and a series of BMPs developed. Initial reactions from US regulators gathered from workshops is also discussed.

Progressing towards the ability to transfer data between MRE projects can aid the industry by satisfying regulatory requirements and shortening siting and permitting processes for MRE development, amplifying understanding of environmental effects, allowing funding resources to be re-directed to help address uncertainty and risk, and standardizing processes for data collection and analysis. The proposed framework modified with feedback from the broader MRE community will contribute to this progress.

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