

# Environmental effects of marine renewable energy: Advancing the industry through broad outreach and engagement

Mikaela C. Freeman, Deborah J. Rose, Andrea E. Copping, Lysel Garavelli, Lenaïg Hemery

**Abstract**—<sup>1</sup> The marine renewable energy industry faces several challenges to scaling-up and acceptance that have hindered its advancement in a multitude of ways, including a lack of information on potential environmental effects. Broad outreach and engagement with a wide variety of audiences focused on specific goals can help address these barriers. OES-Environmental has focused on sharing environmental effects research outcomes and knowledge to broad audiences, including those within the marine renewable energy community and beyond, that are best addressed with a variety of learning formats. Throughout these diverse outreach efforts, several important lessons have been learned. These include identifying an audience for each resource created; developing specific materials for each audience with appropriate language and complexity; leading with a clear message and using a variety of methods and appropriate platforms; and focusing on engaging and creative fact-based products. Creating materials tailored for specific groups has made outreach efforts more effective and has allowed for the information and findings from OES-Environmental to increase awareness of environmental effects of marine renewable energy by reaching new audiences. As OES-Environmental continues to synthesize current scientific knowledge around environmental effects of marine renewable energy, outreach and engagement will continue to be a focus to ensure important findings are communicated to diverse audiences.

**Keywords**—environmental effects, industry advancement, marine renewable energy, outreach and engagement, workforce development

## I. INTRODUCTION

OVER the last decade there has been significant growth within the marine renewable energy (MRE) industry, but several challenges have slowed its advancement. One example is the use of precautionary approaches for MRE deployments due to potential environmental effects [1], [2]. As the industry grows, there is more need to conduct research to fill knowledge gaps and increase understanding of MRE devices and their interaction with the marine environment [3], [4]. This requires a robust and diverse workforce that can contribute to research, deployments, and knowledge sharing.

To overcome challenges facing the MRE industry, outreach and engagement – including science communication – which has been emerging in the literature across multiple fields [5]–[9], can be employed. Resources, tools, and approaches have been developed that provide learning (e.g., [10]) and can be leveraged for MRE projects and strategic communications. The MRE industry can benefit from broad outreach and engagement with a wide variety of audiences to address concerns about potential environmental effects, build a future workforce, share progress on research and development, as well as raise awareness of MRE, generate public support, and achieve success within the larger blue economy.

OES-Environmental is an international initiative under the International Energy Agency (IEA) Ocean Energy Systems (OES), an international technology collaboration program. OES-Environmental is a collaboration between 16 countries that brings together the MRE community to increase understanding of environmental effects of MRE and aid MRE development in an environmentally

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M. C. Freeman is with Pacific Northwest National Laboratory, 1100 Dexter Ave N, Seattle, WA 98109, USA (e-mail: mikaela.freeman@pnnl.gov).

D. J. Rose is with Pacific Northwest National Laboratory, 1100 Dexter Ave N, Seattle, WA 98109, USA (e-mail: deborah.rose@pnnl.gov).

A. E. Copping is with Pacific Northwest National Laboratory, 1100 Dexter Ave N, Seattle, WA 98109, USA (e-mail: andrea.copping@pnnl.gov).

L. Garavelli is with Pacific Northwest National Laboratory, 1100 Dexter Ave N, Seattle, WA 98109, USA (e-mail: lysel.garavelli@pnnl.gov).

L. H. Hemery is with Pacific Northwest National Laboratory, 1529 W Sequim Bay Rd, Sequim, WA 98382, USA (email: lenaig.hemery@pnnl.gov).

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responsible manner. Based on OES-Environmental's 2020 State of the Science Report [11] – a comprehensive technical report providing the most up-to-date review of scientific information on environmental effects of MRE – and additional research produced by the MRE community to date, products have been designed to engage with different audiences. This paper discusses the different audiences, the goals of engaging with each audience, and the specific products that have been created to achieve those goals.

## II. AUDIENCES AND TARGETED OUTREACH

Three audiences have been identified by OES-Environmental for MRE outreach and engagement efforts: A) the MRE community, which includes regulators and advisors, project and device developers, consultants, and researchers; B) science, technology, engineering, and math (STEM) students; and C) the interested public. Each audience has been engaged for different reasons and each group varies in their baseline levels of understanding regarding environmental effects of MRE, leading to specific strategies for engagement being employed based on these factors. All the resources and information developed by OES-Environmental are shared on the online knowledge platform *Tethys*.<sup>1</sup>

### A. MRE community

OES-Environmental's primary audience for outreach and engagement is the MRE community. Materials for the MRE community are created with the goal of sharing current knowledge on environmental effects and making data and information easily accessible. While scientific understanding of interactions between MRE devices and marine animals and the environment has increased over time, a cautionary approach to consenting is often used, which may be due to remaining uncertainty or limited understanding of available information ([11]–[13]). This has created challenges for consenting MRE projects and led to barriers for *in situ* deployments ([14]). In addition, many countries experience a high rate of turnover of regulators and advisors who consent MRE projects, leading to a lack of familiarity with MRE devices among current regulators and advisors who are making or informing consenting decisions ([15]). OES-Environmental engages with MRE regulators and advisors to share current data and information to reduce uncertainty, create tools and guides to aid consenting processes, and make information easily accessible. Developers and consultants are engaged to share products that can be used during consenting processes to aid successful applications and coordination with regulators. OES-Environmental also works with researchers to identify knowledge gaps, propose research recommendations to decrease uncertainty about environmental interactions, and publish

peer-reviewed journal articles to support the research community (e.g., [14], [16]–[18]).

To address these challenges and provide information to aid the advancement of MRE worldwide, OES-Environmental has developed the following materials:

1. State of the Science reports: OES-Environmental is conducted in four-year phases with the culmination of each phase being the production of a State of the Science report ([11], [19], [20]) which comprehensively reviews environmental effects of MRE. The most recent State of the Science report was produced by OES-Environmental in 2020 in collaboration with 40 authors representing 11 countries ([11]). The 2020 report serves as the source material of other materials OES-Environmental has developed (such as the MRE brochure described in the next paragraph) and provides a reference for the MRE community to better understand the interaction between MRE devices and the marine environment. The next State of the Science report will be published in 2024 and will provide an update from the 2020 report and address new areas to help move the industry forward.
2. MRE brochure: Relevant for the MRE community, but developed specifically for new MRE regulators and advisors, a short-form version of the 2020 State of the Science report, called the MRE brochure, was published in March 2022. The brochure provides a high-level overview of environmental effects and is available online in both interactive and printable versions.<sup>2</sup> The brochure contains 22 full-color pages with sections for each environmental interaction as well as photographs and illustrations describing MRE devices. Each section describes the interaction, the current level of risk based on available scientific data, recommendations for minimizing risk, and a real-world case study relevant to consenting for that interaction. The brochure has been shared with regulators and advisors who participated in a series of workshops OES-Environmental held in 2022, with OES-Environmental country representatives to distribute in their respective countries, and in physical form at several international conferences. Since its release, the MRE brochure *Tethys* page has received 1,850 pageviews as of May 2023.
3. Guidance documents: OES-Environmental developed a series of guidance documents that provide in-depth information to aid the application of scientific evidence for consenting (Fig. 1). The guidance documents<sup>3</sup> have three components:
  - Background document: provides a description of the four regulatory categories relevant for MRE consenting (species and populations at risk, habitat alteration or loss, effects on water quality, and effects on social and economic systems) and

<sup>1</sup> <https://tethys.pnnl.gov/>

<sup>2</sup> <https://tethys.pnnl.gov/mre-brochure>

<sup>3</sup> <https://tethys.pnnl.gov/guidance-documents>

a framework for applying risk retirement during consenting.

- Stressor-specific documents: highlight what is currently known about an environmental interaction, the level of risk and an assessment if the risk can be retired, and recommendations.
- Country-specific documents: give an overview of environmental-specific MRE consenting processes in OES-Environmental countries.

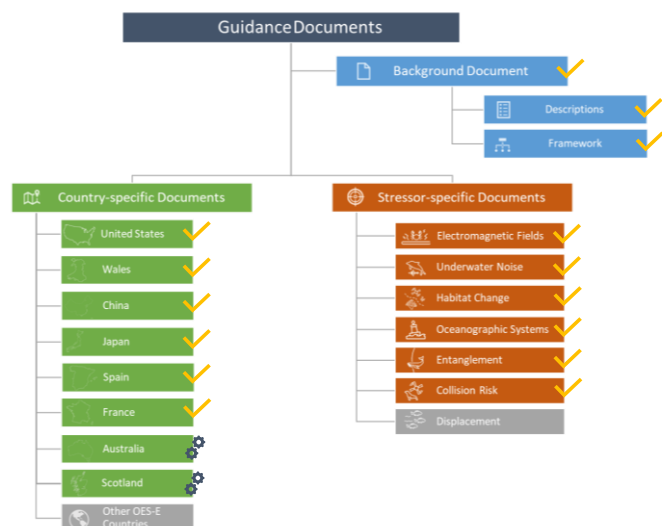


Fig. 1. Overview of guidance documents. The guidance documents include the background document, country-specific documents, and stressor-specific documents. The yellow check denotes completed documents and the dark blue gears denote documents that have been drafted and will be available soon. The grey boxes represent additional documents that will be developed in the future.

The guidance documents are intended for regulators and advisors to help put the scientific material into the context of consenting processes and provide available information for decision-making and for developers and consultants as they develop fit-for-purpose applications. As of May 2023, there have been 1,244 pageviews of the guidance document overview page on *Tethys*.<sup>3</sup>

4. **Management measures tool:** An online tool that documents management measures and mitigation alternatives used in past and present MRE deployments has been created for developers and their consultants for informing future MRE developments. The tool is available on *Tethys* and was updated in 2022.<sup>4</sup> As uncertainties about environmental effects remain, management measures have been developed and applied that help the industry move forward in the face of uncertainty. As of May 2023, and since its release in October 2017, the tool has received 2,295 pageviews.
5. **Expert forums:** Groups of researchers in different regions and nations have been addressing similar technical challenges around measuring MRE effects.

OES-Environmental has convened invitation-only expert forums to bring together research groups addressing similar topics. These small online events allow the participants to be open in sharing results and progress, to share strong opinions, and to encourage collaboration across groups where appropriate. A recent expert forum on displacement of marine animals around MRE devices brought together international experts on marine mammal, fish, and seabird behaviour to understand how potential risks from MRE arrays might affect migrations or movements. The experts identified the need for baseline data on animal distribution and the need to identify spatial and temporal thresholds to better understand the risk and management of displacement.

## B. STEM students

Engaging with STEM students is a new area of outreach for OES-Environmental but has been identified as an important new audience. Materials for STEM students and their teachers were created to educate students about MRE and to explain research that addresses potential environmental effects and allows for deploying MRE devices responsibly. Resources and materials have been produced for primary, secondary, and university students, which cater to the specific knowledge level and needs of different age groups. Engagement materials for STEM students and their teachers include:

1. **Educational Resources Page:** All materials for STEM students are highlighted on the OES-Environmental's *Tethys* Educational Resources Page.<sup>5</sup> This page collates all resources created for STEM students, including the resources listed below. Additionally, the page provides links to additional information that can be found on *Tethys*. The Educational Resources Page was added to *Tethys* in November 2021 and has received 2,053 pageviews as of May 2023.
2. **Marine Energy Video Series:** OES-Environmental and Pacific Northwest National Laboratory Communications created a 4-part animated video series to educate about environmental interactions with MRE devices. The series is available on *Tethys* and consists of an overview video of environmental effects (Fig. 2) and three videos that focus on specific interactions: underwater noise, electromagnetic fields (EMF), and habitat change.<sup>6</sup> Additional videos are planned and will provide information on other environmental interactions. These videos have been shared on *Tethys* social media accounts and newsletters; through OES-Environmental country representatives; and with aquariums, marine-based educational programs, and other venues for STEM education. As of May 2023, and since the videos

<sup>4</sup> <https://tethys.pnnl.gov/management-measures>

<sup>5</sup> <https://tethys.pnnl.gov/marine-renewable-energy-educational-resources>

<sup>6</sup> <https://tethys.pnnl.gov/marine-energy-video-series>

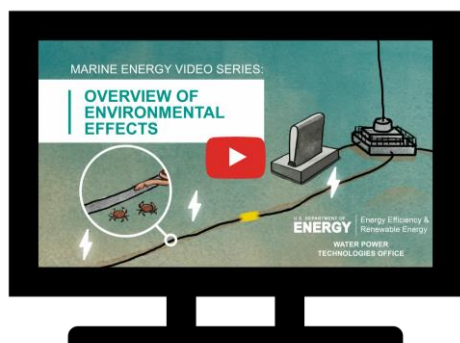


Fig. 2. Thumbnail of overview video, one of the four videos in the Marine Energy Video Series. All videos are available on *Tethys*.

release in June 2022, the overview video has been viewed 311 times, underwater noise 173 times, EMF 137 times, and habitat change 103 times. In addition, the marine energy video series *Tethys* page has received 1,178 pageviews as of May 2023.

3. **Coloring book:** A coloring book<sup>7</sup> was produced as an additional visual format for communicating information about MRE and environmental effects for primary and secondary students. These younger STEM students can engage with the printable handout while learning about MRE. The coloring book has been shared in a manner similar to the marine energy video series. The Fundy Ocean Research Centre for Energy (FORCE) tidal test site in Canada has used the coloring book at their Visitor Centre.
4. **MRE career panel:** To engage university level students who are familiar with MRE and may be interested in a career in the field, OES-Environmental and the Triton Initiative at Pacific Northwest National Laboratory collaborated with the National Renewable Energy Laboratory to hold an MRE-specific career panel in April 2023. The event highlighted a variety of possible careers in the MRE industry from engineers, marine technicians, communications specialists, social scientists to benthic ecologists. Over 130 students registered to attend the event with 58 students attending the event live and 64 viewing the panel recording as of May 2023.

### C. Interested public

Engaging with the interested public is another new area of outreach and engagement for OES-Environmental. Public engagement is particularly important to build awareness of MRE as this helps increase familiarity and understanding (e.g., of MRE technologies, how MRE devices work, etc.) and identify the benefits and potential effects of MRE (e.g., how MRE can fit within community visions, aid energy transitions, support economic development). As there is a shift to move towards 100% renewable energy across the globe, there is inherent value

in having the public understand renewable energy sources. In every industry, public opposition or lack of support for new developments has led to challenges and potential project failure [21], [22]. Therefore, engaging the public to familiarize them with MRE and how devices can be deployed and operated responsibly can lead to more successful outcomes [23]. For this audience, OES-Environmental's role is to develop tools and compile information on environmental effects of MRE to help highlight the opportunity to use MRE, and to explain the research that ensures environmental effects are being managed effectively. Targeted efforts to engage the public have included:

1. ***Tethys* and associated social media:** To share information with the public, OES-Environmental contributes to the *Tethys* website. One of the main features of *Tethys* is the Knowledge Base which aggregates documents and literature on environmental effects. The *Tethys* Knowledge Base has been growing steadily with over 4,000 documents related to environmental effects of MRE and with a steady increase in both site visits and pageviews quarterly (Fig. 3). In addition to the website, *Tethys* social media accounts for Twitter, Facebook, and Instagram are used to engage with the interested public. Through ongoing content creation and continuous efforts in developing and sharing engaging information, all social media accounts have demonstrated increased engagement since 2020.



Fig. 3. Quarterly *Tethys* users since 2013 inception.

2. **Open-access magazine article:** OES-Environmental, in partnership with the Triton Initiative, published an open-access article in the magazine *Sea Technology* ([24]). This article is intended to reach broader audiences with interests relevant to MRE. *Sea Technology* was chosen as a leader in information for marine-based industries and science, with an open-access forum for readers who may be interested to learn more about MRE. The magazine article titled

<sup>7</sup><https://tethys.pnnl.gov/publications/marine-renewable-energy-environment-coloring-book>

“Clean Energy from the Ocean” described MRE and its potential to contribute to renewable energy in the US, highlighted the US MRE industry and deployments to date, introduced environmental effects, and provided an example of how OES-Environmental and the Triton Initiative are working together to better understand environmental effects. The authors shared the article via a LinkedIn post, which has received 922 impressions (screen views) between October 2022, when the article was published, and May 2023.

3. **Relevant podcasts:** To further increase the reach to the interested public and expand general understanding of MRE, several podcast episodes were developed (Fig. 4). Each podcast was selected to represent unique audience interest types, ranging from engineering to conservation to broad energy focus. Since fall of 2021, five podcast episodes have been recorded and released that discuss MRE and highlight OES-Environmental’s efforts.

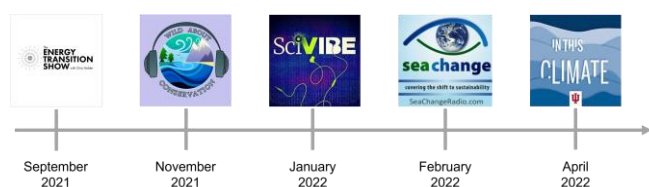


Fig. 4. Podcasts in which an OES-Environmental team member has participated to discuss environmental effects of MRE.

### III. LESSONS LEARNED

Throughout these diverse outreach efforts to increase awareness on environmental effects of MRE, several important lessons have been learned. To create effective messaging, it is important to clarify the main message for each audience and for each educational resource that is created, in order to find the best venue to deliver materials to different audiences, and to use a variety of methods to share messages. For example, engaging young STEM students is most successful with clear and concise messaging and take-aways that are delivered in a simplified and interactive format. The coloring book and the marine energy video series provide similar messages in two unique formats for STEM students. These two resources also highlight the importance of leveraging creative ideas to produce an assortment of engaging and accurate products. Providing multiple ways that different audiences and groups can interact with content enhances the availability of information.

In addition, using language, complexity, and content that suits audience requirements and is age-appropriate is necessary. This is important both when considering age and the complexity of a message, but also when trying to reach an international audience. Key to OES-Environmental has been working with the country representatives to make information as accessible for each

country as possible. For instance, the Executive Summary of the 2020 State of the Science report was translated into Chinese, French, Japanese, Portuguese, and Spanish by the country representatives in an effort to share information with key MRE community audiences into a variety of languages and increase accessibility.

Developing materials with the needs of each audience in mind is key to having successful outcomes. The MRE brochure was specifically created for MRE regulators and advisors after hearing that there is a great deal of turnover in these positions. The brochure can now be used as a resource for those new to the MRE industry to help familiarize them with environmental effects and the state of the science in an abbreviated format with links to additional information.

Collaborating with organizations and initiatives that have similar goals has also been effective in increasing the reach of content and materials. Such collaborations, such as the open-access magazine article and podcast episodes, allow for materials to reach new audiences beyond those specific to OES-Environmental and to highlight synergies between efforts. They also highlight how outreach efforts throughout the MRE community are interrelated and ultimately aim to achieve the advancement of the industry.

Last, expanding efforts, including collaborating with the MRE community, to increase and build the future workforce will greatly aid the industry as it grows. In particular, the breadth of expertise throughout the OES-Environmental team and other initiatives allows for careers available in the MRE field to be highlighted such as through the marine energy career panel. From scientists to engineers to communications specialists there is a range of possibilities for jobs in MRE. Highlighting these different job types required for MRE development and advancing research is important for the industry to succeed and thrive.

### IV. CONCLUSION

Creating materials tailored for specific groups has made outreach efforts more effective and has allowed for the information and findings from OES-Environmental to increase awareness of environmental effects of MRE by reaching new audiences. OES-Environmental approaches information and resource creation with specific objectives in mind for each targeted audience that guides outreach and engagement efforts. For the MRE community, the aim is to share current knowledge on environmental effects and make information easily accessible to aid consenting processes. The State of the Science Report and MRE brochure accomplishes this by familiarizing readers with potential environmental effects and the guidance documents do so by providing information to apply scientific information to consenting processes. Information for STEM students is developed to educate about MRE in general as well as potential environmental effects. The coloring book and video series achieve this by using age-appropriate formats to teach students about MRE. For the



interested public, the objective of outreach is to build broad awareness of MRE and the ways these devices interact with the ocean. The magazine article and podcasts are examples of using available platforms to increase OES-Environmental's reach to the interested public.

As OES-Environmental continues to synthesize current scientific knowledge around environmental effects of MRE, outreach and engagement will continue to be a focus to ensure important findings are communicated to diverse audiences. Sharing lessons learned by OES-Environmental around outreach and engagement can help other researchers and the MRE community broadly to communicate more effectively and accelerate industry progress.

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