# 6.0

# Strategies to Aid Consenting Processes for Marine Renewable Energy

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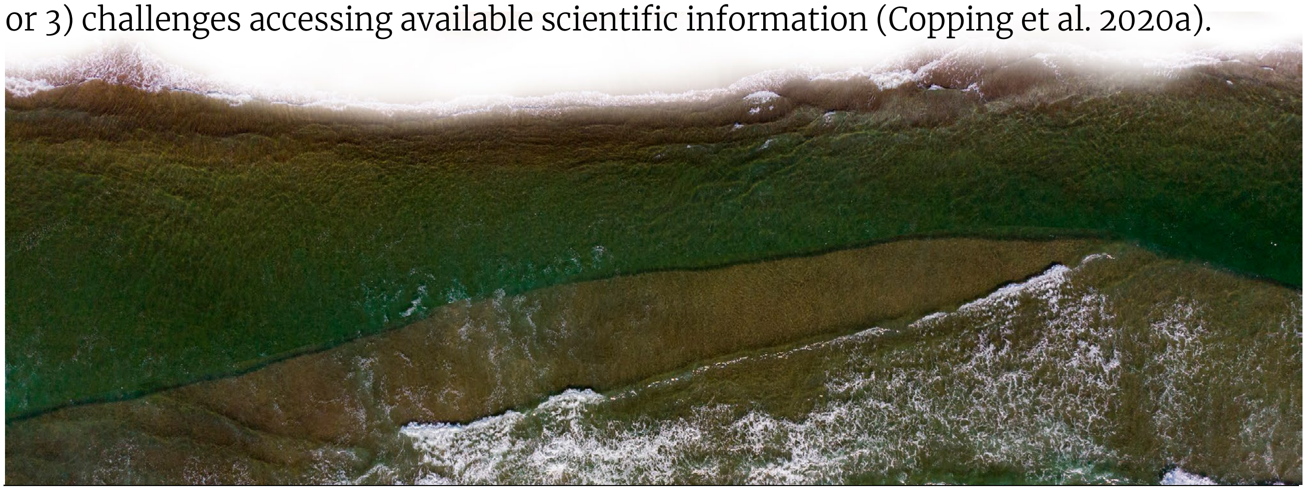
While the marine renewable energy (MRE) industry has made positive strides in the past decade, challenges remain that stall forward progress, scaling up, and commercialization. For MRE to provide a viable solution to address the effects of climate change and achieve sustainable development and renewable energy goals, identifying and understanding barriers and opportunities to deployment is key. Barriers to date have included long consenting timelines, costly in-depth baseline data collection and monitoring requirements, and hesitancy in some countries to approve device and array deployments (Copping & Hemery 2020; Kramer et al. 2020). Some of the key drivers behind these barriers are 1) uncertainty about potential effects of MRE on marine animals, habitats, and the environment; 2) lack of familiarity with MRE technologies; or 3) challenges accessing available scientific information (Copping et al. 2020a).



For example, PacWave South in Oregon, the United States' (US) first pre-permitted commercial-scale, open-ocean wave energy test site navigated an almost 10-year process to receive authorization and dealt with uncertainty about environmental effects that might be caused by devices to be tested in future (Freeman et al. 2022). In another instance, Sustainable Marine Energy Canada Ltd. faced challenges in achieving consent for a tidal energy array at the Fundy Ocean Research Centre for Energy (FORCE) test site in the Minas Passage, Bay of Fundy, which ended with the company choosing to not move forward with its efforts in Canada (Chandler 2024). This decision was primarily driven by regulatory uncertainty about how to manage collision risk to fish. Opportunities to address these barriers and reduce uncertainty include deploying devices at test centers to collect data, share lessons from early developments that can be applied to new projects to reduce onerous baseline data collection and monitoring requirements, and decrease uncertainty through coordinated strategic research and monitoring funded by governments. For example, deployments at the European Marine Energy Centre's (EMEC) test sites in the United Kingdom (UK) have paved the way for tidal and wave energy devices to deploy, monitor, and learn as they go. Pre-and post-installation monitoring data on seabed habitat change at the Voith Hydro HyTide installation at EMEC were used to support consenting at the Brims Tidal Array in Orkney, Scotland, UK. The data indicated that there were minimal impacts on the seabed habitats from foundation drilling and allowed the Brims Tidal Array to adopt a proportionate approach for the environmental impact assessment (EIA), allowing focus on areas of concern with greater uncertainty (Copping et al. 2020a).

Several approaches have been used around the world to support consenting for MRE devices, learn from each development, set precedents that can reduce long timelines for consenting, ease burdensome or disproportional requirements for baseline data collection and monitoring, and advance the industry as a whole. The sections in this chapter provide examples of the strategies, processes, and tools that can aid consenting by examining environmental effects of MRE. This chapter builds on the information presented in Copping et al. (2020a), Le Lièvre (2020), and O'Hagan (2020) to describe updates to processes including risk retirement and data transferability, adaptive management (AM), and marine spatial planning (MSP), as well as how these approaches have been used to support the sustainable development of the MRE sector. The information in Le Lièvre (2020) and O'Hagan (2020) is still largely accurate for AM and MSP, so this chapter focuses on providing brief background and updates since 2020. As such, the majority of this chapter focuses on Ocean Energy Systems (OES)-Environmental's risk retirement and data transferability approaches. This includes OES-Environmental resources and tools such as the guidance documents for risk retirement, monitoring datasets discoverability matrix, and management measures tool. Each section in this chapter begins with a brief overview of information from the *2020 State of the Science* report (Copping et al. 2020a; Le Lièvre 2020; O'Hagan 2020) followed by updates and examples of these approaches from the international MRE industry, and ends with examples of specific tools developed to aid consenting for MRE.

## 6.1. RISK RETIREMENT AND DATA TRANSFERABILITY

Risk retirement and data transferability have been used in other industries (health, transportation, land management, etc.) including MRE (Bridge et al. 2020; Drummond et al. 2009; Gransberg et al. 2018; ORJIP Ocean Energy 2022a; Robertson et al. 2018; Václavík et al. 2016), though often the application of these processes is not identified using these terms, or more commonly is not well documented and disseminated. For example, risk retirement is similar to the concept of a Proportionate EIA used in the UK (IEMA 2017).

Risk retirement for MRE, as defined by Copping et al. (2020a), aims to reduce barriers to consenting MRE developments by:

- Increasing the accessibility of existing scientific information and use of this information through data transferability;
- Providing an approach to assess risk and determine the ability to retire risks where evidence shows the level is low;
- Offering guidance to distinguish between perceived (but unknown) and actual risks, and to apply current information and data to consenting processes; and
- Identifying which risks remain uncertain or undetermined, requiring more research to increase understanding.

## WHAT IS RISK RETIREMENT?

A process for facilitating consenting for MRE developments whereby each potential environmental risk need not be fully investigated for every project. Instead, regulators, advisors, developers, and consultants can rely on what is known from consented MRE projects, related research studies, or findings from analogous offshore industries to help determine which interactions are better understood and can be considered retired or low risk. If new information becomes available, a retired risk can (and should) be re-examined and a new decision made about risk retirement.

This process aims to distinguish between perceived and actual risk, provide assistance for regulatory decision-making, and inform the MRE community what is likely to be required for consenting MRE projects.

Risk retirement does not take the place of any existing regulatory processes or replace the need for appropriate data collection before, during, and after MRE device deployment.

(Copping et al. 2020a)

The risk retirement process is offered for regulators and advisors to assist with decision-making throughout consenting processes and for developers and consultants as they prepare applications for MRE developments.

Copping et al. (2020a) offer in-depth information on risk retirement and data transferability, as developed by OES-Environmental, with feedback from regulators and advisors in OES-Environmental countries and throughout the international MRE community. These processes and associated tools aim to compile existing scientific information on environmental effects of MRE into formats that are easily accessible and applicable for consenting and licensing MRE developments to help satisfy regulatory requirements and increase understanding (Figure 6.1). A risk retirement pathway was created to determine the level of risk for potential stressor-receptor interactions (see Chapter 3). The pathway has a series of steps to assess if an interaction can be retired, highlight solutions based on available evidence, and chart a proportionate approach to identifying gaps in knowledge. A data transferability process was also developed, including a framework for its application, guidance for data collection consistency, best management practices, and an online tool—the monitoring datasets discoverability matrix—for discovering analogous datasets. Other components include evidence bases (see Section 6.1.1.), a management measures tool to inform the use of management (or mitigation) measures when effects may be uncertain, and guidance documents for risk retirement which bring together risk retirement, evidence bases, and associated tools to guide application for consenting (see Section 6.1.2.). Additional resources, like the brochure MRE: An Introduction to Environmental Effects, created for regulators or those new to the industry, are provided as an introduction to environmental effects of MRE, and are also available.

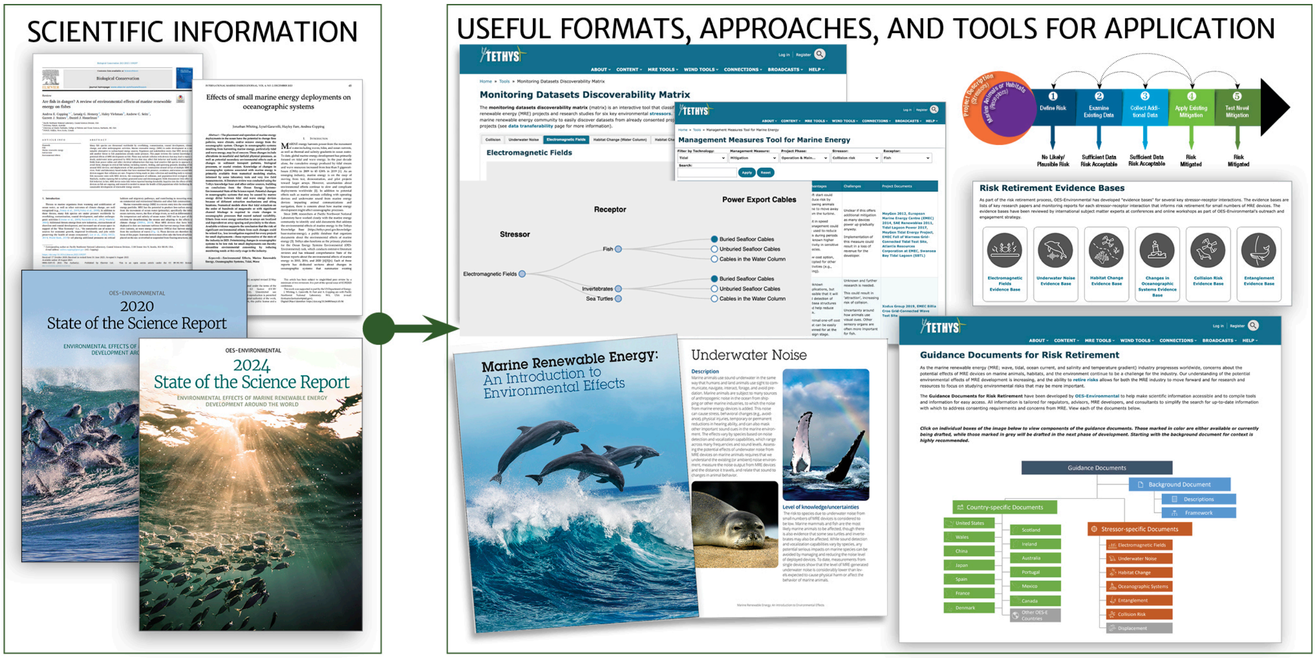



**Figure 6.1.** Depiction of the process to move from available science on environmental effects of marine renewable energy (MRE) to application for consenting processes. Information including Ocean Energy Systems (OES)-Environmental's *State of the Science* reports, existing data and information from MRE developments, and peer-reviewed literature on environmental effects of MRE are compiled and organized into formats useful for specific audiences or contexts.

## 6.1.1. ASSESSING ENVIRONMENTAL INTERACTIONS FOR RISK RETIREMENT

During 2019-2020, OES-Environmental identified two stressor-receptor interactions, electromagnetic fields (EMFs) and underwater noise, as candidates for risk retirement for small numbers of devices (Copping et al. 2020a). Evidence bases were created for each of these interactions, consisting of key documents that best inform the evaluation of the state of understanding and risk level. These documents include journal articles, research papers, and monitoring reports primarily from the US, European Union, UK, and Canada. For risk retirement purposes, the available environmental effects information applies to small numbers of devices (about one to six) and primarily to full-scale (or close to full-scale) devices. While MRE devices vary in size and configuration—with some creating large amounts of power, while others generate less—the available studies do not provide much guidance on how to estimate the incremental risk based on these differences.

Grounded by the available evidence bases, experts and practitioners in the MRE community were consulted to evaluate risk retirement. Consensus was reached to accept the evidence for risk retirement of both interactions for small numbers of devices, with some caveats and additional data collection needs identified (Copping et al. 2020a; Copping et al. 2020b). For example, needs for underwater noise include a library of standardized noise measurements from individual MRE device types and models and *in situ* noise measurements for new devices deployed using the International Electrotechnical Commission (IEC) Technical Committee 114 Level B recommendations (Copping et al. 2020a; Copping et al. 2020b; International Electrotechnical Commission 2019a). For EMFs, while implementing management measures such as burying cables helps satisfy some regulatory concerns, remaining data gaps and needs include developing reliable EMF sensors, collecting field data to validate and improve numerical models, and creating regulatory thresholds for EMFs (Copping et al. 2020a; Copping et al. 2020b; Hasselman et al. 2023).

Since 2020, three additional stressor-receptor interactions have been identified as candidates for risk retirement for small numbers of devices: changes in habitat, changes in oceanographic systems, and entanglement. Beyond these, other environmental interactions require additional strategic research, such as collision risk and displacement. Table 6.1 provides a summary of risk retirement for each stressor-receptor interaction, based on available data and information. Each of these interactions is addressed in further detail in Chapter 3.

**Table 6.1.** Overview of risk retirement for each stressor-receptor interaction based on evidence bases and feedback from Ocean Energy Systems (OES)-Environmental international workshops and consultations with experts. For each interaction, evidence bases provide citations and references for understanding the level of risk. Small numbers of devices are generally considered between one to six devices.

| STRESSOR-RECEPTOR INTERACTION | READINESS FOR RISK RETIREMENT |
|---|---|
| Collision risk | Need more information. |
| Underwater noise | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
| Electromagnetic fields | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
| Changes in habitat | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
| Oceanographic systems | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
| Entanglement | Need more information as the industry moves to larger-scale arrays. |
| Displacement | Need more information as the industry moves to larger-scale arrays. |

### CHANGES IN HABITAT

Evidence from monitoring around single MRE devices, field research, and information from other marine industries indicate that impacts from changes in habitat are limited and unlikely to cause harm to marine animals and the environment (Hemery 2020; Hemery et al. 2021; OES-Environmental 2022a). Based on the available literature, consultation with the MRE community, and evaluation of risk retirement, there is consensus among experts that for small-scale developments, the risk of changes in habitats can be retired if such developments are properly sited to avoid sensitive or unique habitats.

### CHANGES IN OCEANOGRAPHIC SYSTEMS

Evidence from field measurements and numerical modeling suggests that for single devices and small arrays, changes in oceanographic systems will not be detectable above the natural variability in ocean conditions at a site (OES-Environmental 2022b; Robins et al. 2014; Whiting et al. 2023; Yang et al. 2013). There is consensus among experts that for small-scale developments the risk can be retired. As the industry scales up, this risk will need to be reassessed to better understand impacts from large-scale arrays, to study cumulative impacts from these and other marine developments, and to address remaining uncertainties.

### ENTANGLEMENT

MRE device mooring lines have no loose ends and are maintained taut during operation and under sufficient pressure to prevent a loop from forming that can entangle large marine animals. Due to these characteristics and the mass and size of mooring lines and cables used in MRE developments, the risk of entanglement is considered low or non-existent for single devices and small arrays (OES-Environmental 2023). Some stakeholders have concerns that derelict fishing gear or other marine debris could be caught on mooring lines or cables, posing a secondary entanglement risk to marine animals. However, this risk has never been demonstrated and can likely be mitigated by periodic visual inspection and removal of such materials.

## 6.1.2. GUIDANCE DOCUMENTS FOR RISK RETIREMENT

Guidance documents that make scientific information readily available, compile tools and information for easy access, and provide a framework for application have been developed by OES-Environmental to apply risk retirement during consenting processes (Figure 6.2) (Copping et al. 2021; Freeman et al. 2024). These documents are tailored for regulators, advisors, developers, consultants, and other stakeholders, and have been written to be generally applicable internationally. They include:

1. A background document that provides an overview of risk retirement and the guidance documents, descriptions of four regulatory categories relevant for MRE consenting—species and populations at risk, habitat loss or alteration, effects on water quality, and effects on social and economic systems—and how they map to key stressor-receptor interactions, and a framework for how to apply risk retirement and data transferability within consenting processes;
2. Stressor-specific documents that provide an overview of the state of knowledge for each stressor-receptor interaction, links to existing data and information, a description of risk retirement, and recommendations to advance understanding; and
3. Country-specific documents that provide an overview of the MRE regulatory context within each OES-Environmental country.

## 6.1.3. DATA TRANSFERABILITY

As more MRE devices are deployed with baseline assessments and post-installation monitoring, available data and information on potential environmental effects will increase, improving the knowledge base to inform future MRE developments and the risk retirement process. Leveraging existing information through data transferability—the application of existing learning, analyses, monitoring data, and information from one project, jurisdiction, or country to another—can help lead to more efficient environmental consenting processes (Copping et al. 2020a; Kramer et al. 2020). Collecting data in a consistent manner will support the transfer of data and comparison of results

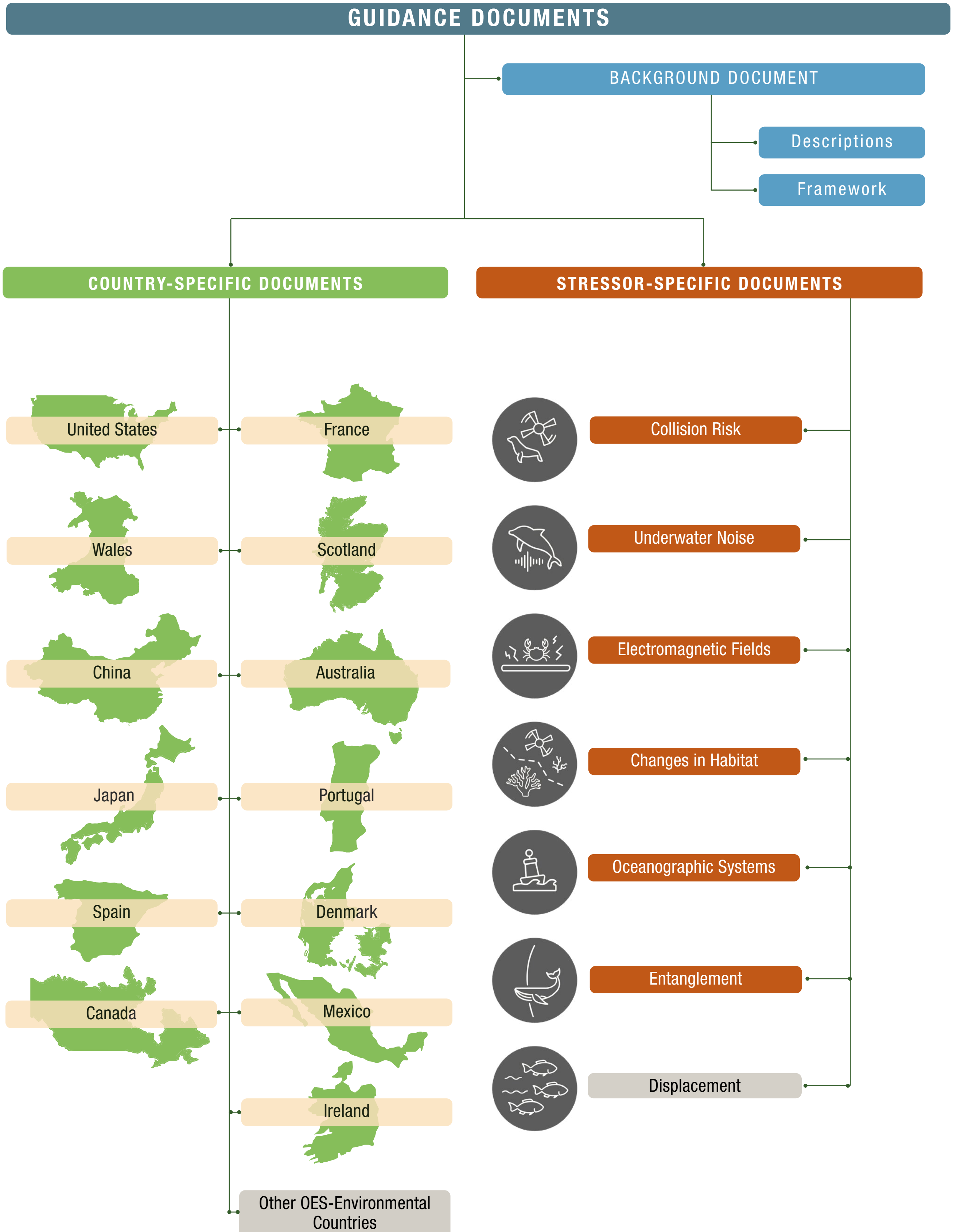
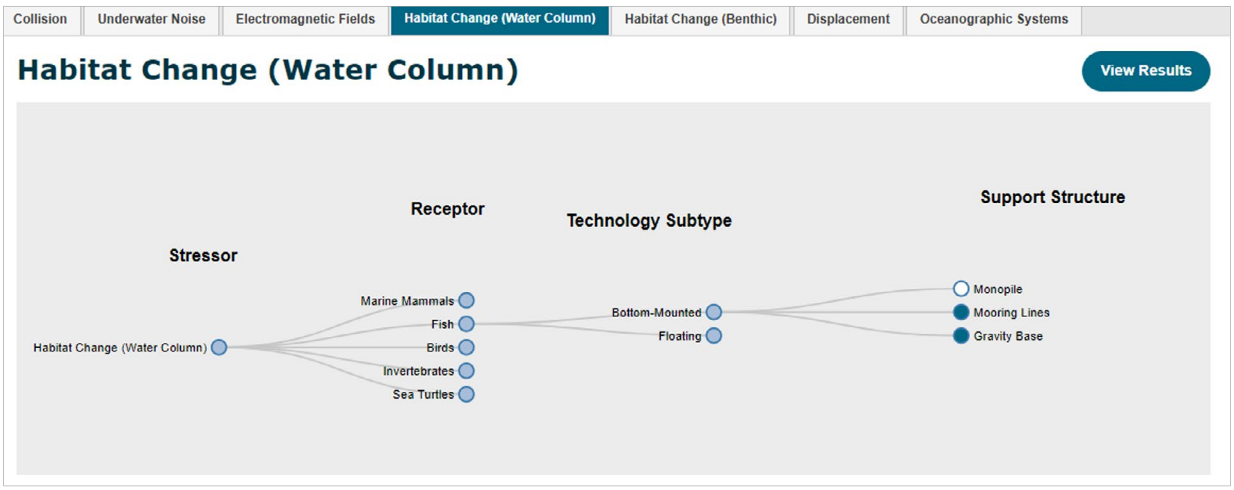



**Figure 6.2.** Overview of the guidance documents for risk retirement. Colored boxes indicate completed guidance documents. Boxes in grey indicate next steps in the development of the guidance documents. Each of the individual guidance documents can be accessed via the links in the figure.

among MRE projects. Eaves et al. (2022) highlight the lack of standards for environmental monitoring and identify monitoring technologies and methods that will result in consistent data collection for four key stressor-receptor interactions, and ultimately assist with data transferability. Recommendations for monitoring collision risk, underwater noise, EMFs, and changes in benthic habitat are detailed in Staines et al. (2022), Haxel et al. (2022), Grear et al. (2022), and Hemery et al. (2022), respectively.

Data transferability hinges on the accessibility of applicable datasets that are relevant for new MRE developments. At the request of regulators, OES-Environmental developed a monitoring datasets discoverability matrix (matrix) to catalog and easily identify available and relevant datasets to be used to transfer learning and information. The matrix is structured by key stressor-receptor interactions and includes characteristics for each interaction to define similar attributes for transfer (Figure 6.3). These characteristics can be selected from




## Monitoring Datasets Discoverability Matrix Results

The listing below provides you the results of your choices of characteristics such as **stressors, receptors**, site conditions, technology types, and project scale. Baseline and Post-Installation Monitoring results are based on **OES-Environmental metadata**, which provides information on past or existing MRE projects or around test sites, and are filtered by all characteristics chosen. Research Study results are based on OES-Environmental metadata forms that focus on MRE research, and are filtered by only stressor and receptors. Key Document results are a compilation of papers and reports key to understanding the stressor.

Habitat Change (Water Column) >> Fish >> Bottom-Mounted >> Gravity Base
Habitat Change (Water Column) >> Fish >> Bottom-Mounted >> Mooring Lines
**Search Matrix:**

### Baseline & Post-Installation Monitoring

| Title | Description | Country |
|---|---|---|
| **Biscay Marine Energy Platform (BiMEP): Baseline - Fish** | Literature review of impacts on fish. | Spain |
| **Biscay Marine Energy Platform (BiMEP): Post-Installation - Fish** | Impact on fish communities due to potential reef effect of floating devices. | Spain |
| **CalWave xWave Demonstration: Post-Installation - Fish** | Monitor fish activity for habitat change studies. | United States of America |
| **Cobscook Bay Tidal Energy Project: Post-Installation - Fish** | The goal of the Fisheries and Marine Life Interaction Monitoring Plan was to collect pre-deployment and post-deployment information to provide an initial description of fish distribution and relative abundance within Cobscook Bay to supplement existing information for the general Passamaquoddy Bay area. The Fisheries Monitoring Plan is a continuation of research started by UMaine researchers in 2009. | United States of America |

**Figure 6.3.** Example of the monitoring datasets discoverability matrix (matrix) for changes in habitat within the water column, including the characteristics related to this stressor-receptor interaction and results from the matrix query. This example shows baseline and post-installation monitoring but does not show additional matrix results including research studies from change to: Ocean Energy Systems (OES)-Environmental's metadata collection as well as key documents from the changes in habitat evidence base.

the matrix to discover available data and information from MRE and analogous industries (e.g., offshore wind, offshore oil and gas) that can be used to inform consenting and understanding of new MRE projects.

Using the best practices for data transfer described in Copping et al. (2020a) and the matrix can help the MRE community transfer data and information gained from past and current projects to inform future developments, with the aim of easing requirements for baseline data collection and monitoring.

## 6.1.4. CASE STUDIES OF RISK RETIREMENT AND DATA TRANSFERABILITY

The principles of risk retirement and data transferability have been implemented in the MRE industry, but often are not documented or identified as "risk retirement". Sharing examples of how MRE projects have employed these processes can help to build confidence in their application for future projects. This section highlights eight case studies from the MRE industry where risk retirement, as well as data transferability, have occurred. At the end of each case study, a summary table details how each MRE development navigated potential risk, matched to the steps in the risk retirement pathway (Figure 6.4).

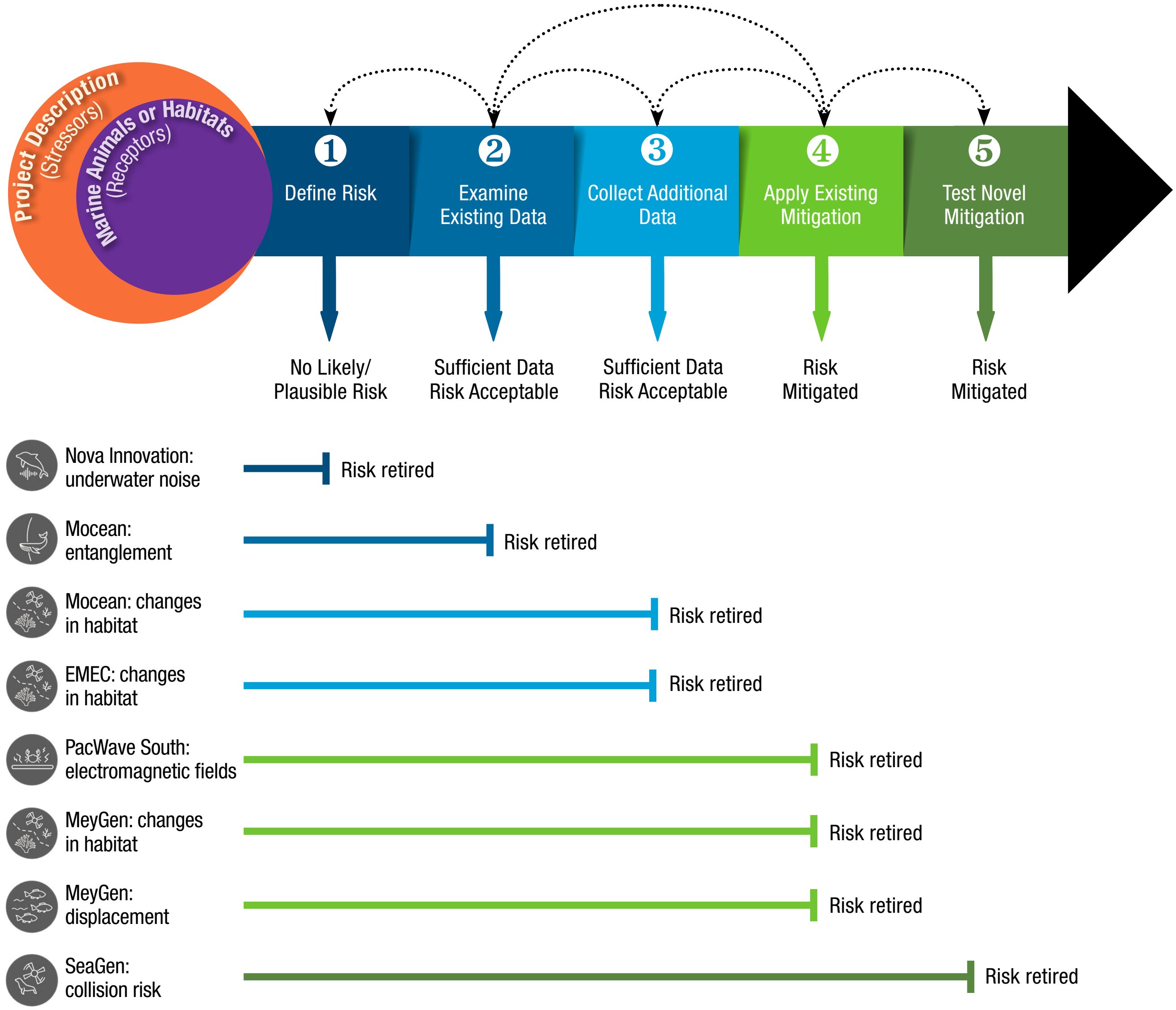



**Figure 6.4.** Risk retirement pathway demonstrating its use in eight case studies. The colored lines below the risk retirement pathway demonstrate the applicability of each MRE development to steps in the pathway, and where risk retirement was achieved. EMEC = European Marine Energy Centre.

## NOVA INNOVATION SHETLAND TIDAL ARRAY – UNDERWATER NOISE

*Contributed by Kate Smith (Nova Innovation)*

**Project Description:** Operational 0.6 MW project in Bluemull Sound, Shetland, Scotland (Figure 6.5), comprised of six, two-bladed, 100 kW horizontal axis turbines on seabed gravity support structures. Three of the turbines are Nova Innovation's original geared design and three are next-generation direct drive (gearless) turbines. The turbines are connected to the main Shetland grid and have been powering residences since 2016, and electric cars through a vehicle charging point since 2018.

**Stressor-receptor interaction:** Underwater noise from operational turbine resulting in injury or behavioral responses (disturbance or displacement) in key sensitive species such as marine mammals.

**Pathway to risk retirement:** A detailed quantitative noise assessment was not required by Marine Scotland (now Marine Directorate) or NatureScot (previously Scottish Natural Heritage) for Nova Innovation's license applications for the Shetland Tidal Array, due to the small size and number of turbines (Marine Scotland 2024; Smith 2024). Land-based bird and mammal surveys and turbine-mounted subsea cameras used as part of Nova Innovation's adaptive Project Environmental Monitoring Plan have demonstrated that the project had not resulted in any disturbance or displacement of marine mammals from Bluemull Sound (see Nova Innovation case study in Section 6.2.2).

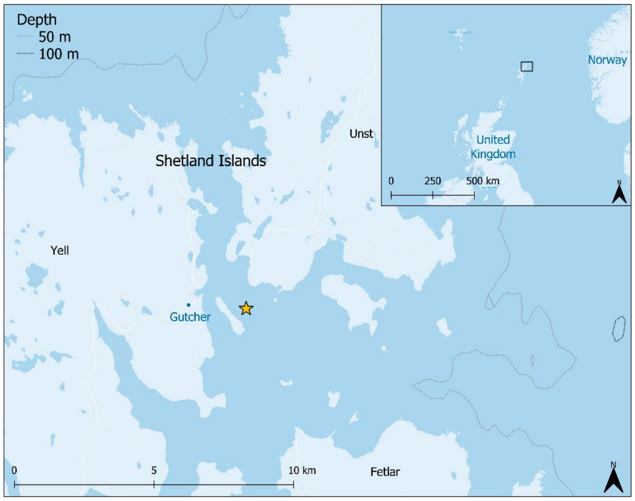



**Figure 6.5.** Location of the Nova Innovation Shetland Tidal Array in Scotland, United Kingdom (yellow star).

The assessment of subsea noise is likely to become an increasingly important part of consenting tidal energy projects as they increase to commercial scale. In recognition of this, Nova Innovation worked with Offshore Renewable Energy Catapult to measure the noise generated by the turbines in the Shetland Tidal Array to de-risk consenting of future projects.

The work was undertaken when all six turbines were installed and operating in Bluemull Sound[1], and showed that even prolonged exposure of sensitive species at close range to Nova Innovation's turbines is not likely to result in injury, based on established thresholds for sound pressure levels (Southall et al. 2019). Some localized behavioral response (evasion) close to the turbines may occur; this evasion may help to reduce collision risk for turbines.

**Conclusion:** The risk of injury or behavioral responses from underwater noise was retired for the Shetland Tidal Array based on the small size and number of turbines. A detailed qualitative noise assessment was not required by Marine Scotland or NatureScot for consenting, and no noise monitoring was required during the operational phase of the project.

**Summary of risk retirement:**

DEFINE RISK

- Underwater noise from operational turbine resulting in injury or behavioral responses in key sensitive species such as marine mammals.
- The characteristics of the project were defined, and due to the small size and number of turbines a detailed quantitative noise assessment was not required for the license application.

1. The three geared turbines were in situ at the time of the work detailed in this case study but were decommissioned in 2023.

## MOCEAN ENERGY – ENTANGLEMENT

*Contributed by Shane Quill (Aquatera Ltd.) and Jon Clarke (Mocean Energy)*

**Project Description:** One wave energy converter (WEC) system (BlueX) off the coast of Orkney (east of Deerness), Scotland (Figure 6.6) with an umbilical and associated mooring lines, covering a small footprint (0.05 km$^2$) (Marine Scotland, 2023, 2019a).

**Stressor-receptor interaction:** Risk of entanglement in mooring lines or cables for cetaceans and basking sharks (*Cetorhinus maximus*).

**Pathway to risk retirement:** NatureScot conducted a study of entanglement risk in 2014, which concluded that MRE mooring lines are unlikely to pose a major entanglement threat to cetaceans and basking sharks as they have too much tension to create a loop and do not have loose ends (Benjamins et al. 2014). The study notes that while there is a greater risk of entanglement for large baleen whales (e.g., fin whale, *Balaenoptera physalus,* or humpback whale, *Megaptera novaeangliae*) due to their large size and feeding behavior (Benjamins et al. 2014), the likelihood of their occurrence at the proposed deployment site was considered very low, and humpback whales in particular are rare visitors to Orkney waters (Evans et al. 2011).

**Conclusion:** Using this available baseline information and the technical project information, an assessment of the risk posed by the presence of a single WEC, umbilical, and two associated taut mooring lines with a relatively small footprint, concluded that there was no significant entanglement risk for cetaceans or large baleen whales (Aquatera Ltd 2021). A commitment to reporting any notable entanglement events to the regulator within 24 hours of observation was included in the project mitigation and monitoring plan (Aquatera Ltd 2021).

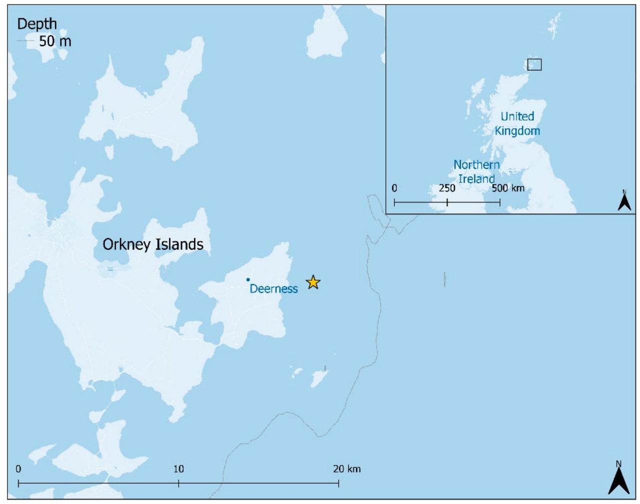



**Figure 6.6.** Location of the Mocean Energy in Scotland, United Kingdom (yellow star).

**Summary of risk retirement:**

### DEFINE RISK

- Risk of entanglement in mooring lines or cables leading to injury or death of large cetaceans and basking sharks.

### EXAMINE EXISTING DATA

- A government-commissioned study concluded that mooring lines associated with MRE devices are unlikely to pose a major threat of entanglement risk to cetaceans and basking sharks (Benjamins et al. 2014).
- A relative risk assessment for entanglement was undertaken as outlined in Benjamins et al. (2014). This confirmed that species of most concern (large baleen whales) were not in the area of the deployment and therefore not an issue.

## MOCEAN ENERGY – CHANGES IN HABITAT

*Contributed by Shane Quill (Aquatera Ltd.) and Jon Clarke (Mocean Energy)*

**Project Description:** One WEC system (BlueX) off the coast of Orkney (east of Deerness), Scotland (Figure 6.6) with an umbilical and associated mooring lines, covering a small footprint (0.05 km$^2$) (Marine Scotland 2023, 2019a).

**Stressor-receptor interaction:** Changes to benthic habitats and species during installation of the mooring system.

**Pathway to risk retirement:** At the license application stage, the mooring system consisted of a combination of nylon and chain mooring lines and associated clump weights. No drilling was proposed for the mooring system installation, therefore potential disturbance from the installation was considered highly localized and temporary in nature.

A study commissioned by NatureScot in 2011 concluded that "sublittoral sand biotopes... are of widespread occurrence throughout Scotland and the UK and at least surface observation of the sediment suggests impoverished faunas, especially in the highly mobile sediments of the southwestern region of the Pentland Firth" (Moore & Roberts 2011). A benthic survey carried out in 2019 by the project team confirmed that the deployment area was consistent with the previous survey conducted by NatureScot (Aquatera Ltd 2021), which reported the presence of sublittoral sand biotope to the east of Holm Sound where there were few signs of infaunal life and a sparse epifaunal community mainly composed of widely scattered echinoderms. The assessment concluded that due to the nature of the proposed work and the mooring system, potential disturbance was considered to be highly localized and temporary in nature. No specific mitigation was proposed in relation to this impact during the deployment and operation of the BlueX WEC system.

**Conclusion:** The presence of a single WEC and associated mooring system was anticipated to result in minimal disturbance of sensitive/protected habitats at the deployment site (Marine Scotland 2019, 2023).

**Summary of risk retirement:**

DEFINE RISK

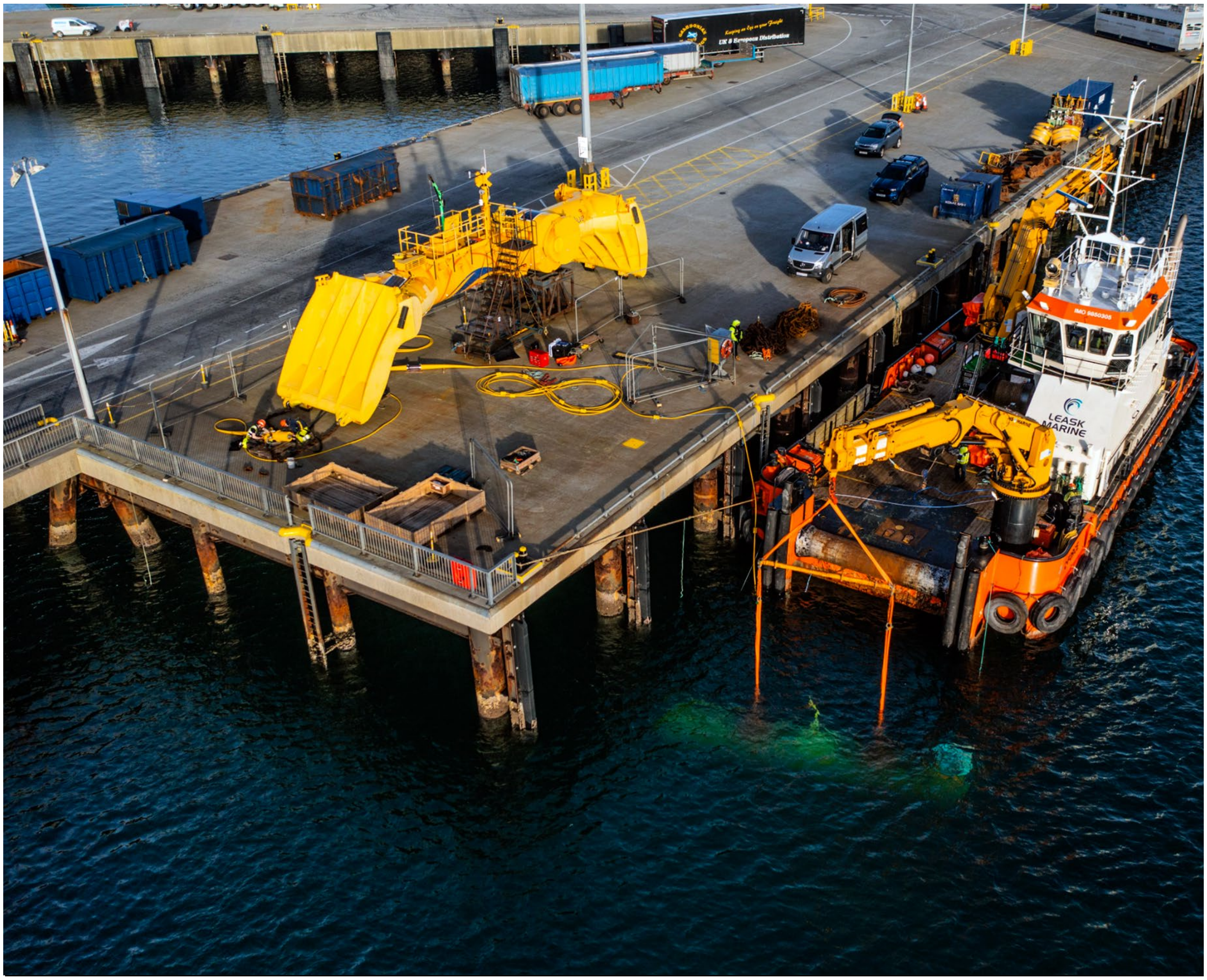
- Risk of benthic habitat disturbance from installation of the mooring system.

EXAMINE EXISTING DATA

- A government-commissioned study confirmed that the wider geographic area did not contain protected or sensitive habitats (Moore & Roberts 2011).

COLLECT ADDITIONAL DATA

- A further project-specific survey was conducted to confirm the findings of the government-commissioned study (Aquatera Ltd 2021).
- Disturbance of sensitive/protected habitats was considered to be limited (highly localized and temporary in nature), therefore no specific mitigation was proposed.



## EMEC, FALL OF WARNESS TIDAL TEST SITE AND BILLIA CROO WAVE TEST SITE – CHANGES IN HABITAT

*Contributed by Ian Hutchison and Jennifer Fox (Aquatera Ltd.)*

**Project description:** Grid-connected test sites off the coast of Orkney, Scotland at EMEC (Figure 6.7) for testing and demonstration of large-scale tidal and wave energy technologies in the open ocean.

**Stressor-receptor interaction:** Changes to benthic habitats.

**Pathway to risk retirement:** Baseline benthic surveys were undertaken during the EIA process for the Fall of Warness and Billia Croo test sites in 2002 and 2005, respectively (Carl Bro Group Ltd 2002; Foubister 2005). Developers planning to deploy and test their wave or tidal device at either of these sites were required to prepare an Environmental Mitigation and Monitoring Plan, which in most instances, included a commitment to undertake pre- and post-installation and post-decommissioning benthic surveys. Following a review by the EMEC Monitoring Advisory Group in 2012, the regulator (Marine Scotland) issued a communication that benthic surveys would no longer be required under license conditions due to the sufficiency of previously collected data (Marine Scotland 2013a).

**Conclusion:** Based on available and collected data, no significant effects on benthic habitats from installation, operation, and removal of wave and tidal devices were observed. As such, the licensing requirement to undertake pre- and post-installation and post-decommissioning benthic surveys was removed (Marine Scotland, 2013a).

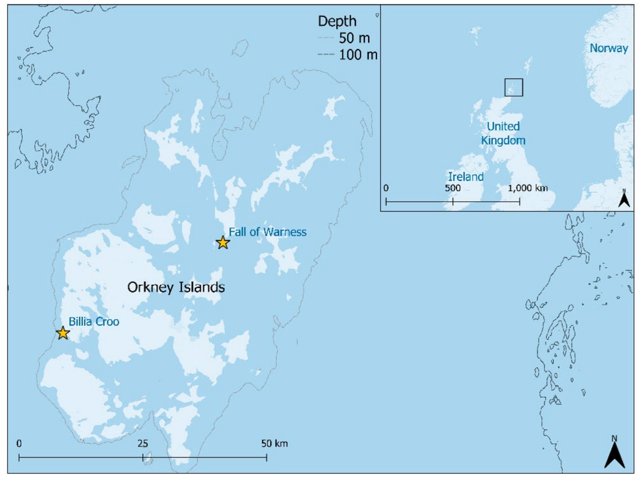



**Figure 6.7.** Locations of European Marine Energy Centre (EMEC) test sites (Billia Croo and Fall of Warness) in Scotland, United Kingdom (yellow stars).

**Summary of risk retirement:**

### DEFINE RISK

- Risk of benthic habitat change from installation, operation, and removal of large-scale wave and tidal energy devices.

### EXAMINE EXISTING DATA

- For the Fall of Warness tidal test site, benthic survey data were collected as part of the original EIA by Aquatera (Foubister 2005).
- For the Billia Croo wave test site, an underwater survey (still images and video), a sediment core survey, and a littoral survey were carried out by Heriot-Watt University's International Centre for Island Technology (Carl Bro Group Ltd 2002).

### COLLECT ADDITIONAL DATA

- Developers were required to undertake site-specific pre- and post-installation and post-decommissioning benthic surveys.
- As no significant effects were observed with the additional data collected, benthic surveys were no longer required under license conditions.

## MEYGEN TIDAL ENERGY PROJECT – CHANGES IN HABITAT

*Contributed by Jennifer Fox and Ian Hutchison (Aquatera Ltd.), and Ian M. Davies (Carronside Consultancy Ltd.)*

**Project description:** MeyGen is a large commercial-scale tidal array development off the north coast of Scotland (Figure 6.8). MeyGen was awarded an 'agreement for lease' from the UK Crown Estate in 2010, to develop a tidal array up to 398 MW. Phase 1 of the project was granted planning consent from Scottish Ministers for up to 86 MW (or 61 tidal turbines) in 2013 (Marine Scotland 2013b). The first stage of the project (Phase 1A) was limited to the installation and operation of six turbines, with expansion subject to the findings from environmental monitoring around the first turbines. Four 1.5 MW horizontal axis turbines on gravity bases were installed and have been operating since March 2018. The turbines are connected to the power grid at the Ness of Quoys, generating approximately 62 GWh of power as of April 19, 2024.

**Stressor-receptor interaction:** Changes in benthic habitats and species in the study area along the cable route and at the turbine locations.

**Pathway to risk retirement:** During consenting, a number of relevant potential impacts were considered as part of the EIA process including direct physical impact and loss of habitat, introduction of new hard structures, and sediment disturbance (MeyGen 2012). Existing site data were reviewed (Scottish Government 2014; JNCC 2024) and, through stakeholder consultation, additional data were requested to determine the presence of benthic habitats and species in the study area. Data collected from a geophysical survey and two benthic surveys showed that no habitat or species of conservation concern were present at the project site and therefore were not likely to be impacted (MeyGen 2012). For extra protection, design features (minimizing the depth and diameter of the turbine foundation piles) and mitigation measures (restricting the area of kelp clearing, including by clearly defining the installation layout) for construction were built into the project (MeyGen 2012). Following the EIA process, consent was granted for Phase 1. A Project Environmental Monitoring Programme (PEMP) was required based on relevant consent conditions (The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2000) and was developed by MeyGen with a technical Advisory Group (Rollings et al., 2016a). Benthic habitats along the export cable route and at the turbine locations were also considered during the preparation of the PEMP, but based on the existing and collected data, no benthic habitat monitoring was proposed as no significant impacts were expected from Phase 1A. After consultation with statutory nature conservation bodies (NatureScot, Scottish Environmental Protection Agency), relevant research organizations, and other consultees, the PEMP was accepted by Marine Scotland as the licensing authority (Marine Scotland 2016).

Figure 6.8. Location of MeyGen Tidal Energy project in Pentland Firth, Scotland (yellow star).

**Conclusion:** Based on the scale and layout of the project, an examination of existing data from the site, data collected during the surveys, and the advice from the MeyGen Advisory Group, the risk of any significant impacts on benthic habitats was retired for the first stage of the project and no mitigation or monitoring was required during for operation.

**Summary of risk retirement:**

### DEFINE RISK

- Potential risk of impact to benthic habitats and the animals that reside within that habitat.

### EXAMINE EXISTING DATA

- Existing benthic habitat data were examined as part of the EIA process.

### COLLECT ADDITIONAL DATA

- Benthic seabed surveys were carried out to determine the benthic habitats and species present and the biotope classification. These data were then examined during the EIA, the conclusions of which informed the development of the PEMP.
- Monitoring of benthic habitats and species was not required for the operational stage.

### APPLY EXISTING MITIGATION

- No mitigation required during the operational stage.
- Design features and mitigation measures for the construction stage were built into the project to mitigate potential impacts.

MEYGEN TIDAL ENERGY PROJECT – DISPLACEMENT

*Contributed by Jennifer Fox and Ian Hutchison (Aquatera Ltd.), and Ian M. Davies (Carronside Consultancy Ltd.)*

**Project Description:** MeyGen is a large-scale commercial tidal array development off the north coast of Scotland (Figure 6.8) with Phase 1 of the project granted planning consent for up to 86 MW (or 61 tidal turbines) (Marine Scotland 2013b). The first stage of the project (Phase 1A) consists of four, 1.5 MW horizontal axis turbines (6 MW installed capacity) on gravity support structures that were installed and have been operating since March 2018.

**Stressor-receptor interaction:** Displacement of marine mammals, birds, and basking sharks (*Cetorhinus maximus*).

**Pathway to risk retirement:** Another potential issue identified during the EIA process was effects on marine mammals, birds, and basking sharks from displacement due to the presence of the turbines, physical barriers to movement, displacement due to underwater noise from operational turbines, and indirect effects via changes to prey species (MeyGen 2012). A desktop review of existing data; boat- and shore-based survey data to determine marine mammal distribution, abundance, seasonality, and behavior; ambient noise collected via a towed hydrophone; and benthic survey data were examined (MeyGen 2012). Based on this information, the EIA concluded:

- **Marine mammals** – The impact on marine mammals' ecology is expected to not be significant with implementation of proposed mitigation strategies during construction.
- **Birds** – Due to the relatively small scale of the project and the sensitivity of each species considered to the relevant sources of potential displacement, no significant impacts were identified.
- **Basking sharks** – Due to the relatively small scale of the project and the implementation of mitigation strategies during construction, the impact on basking sharks was considered to not be significant.

Following the EIA process, consent was granted for Phase 1 in 2013 (Marine Scotland 2013b), subject to a PEMP. One element of consideration for the PEMP was displacement of marine mammals, seabirds, and basking sharks during construction and operation. An Advisory Group, made up of representatives from MeyGen, Marine Scotland, NatureScot, and The Crown Estate (now The Crown Estate and Crown Estate Scotland) produced a report to be used for developing the PEMP that concluded "disturbance and displacement impacts (Condition 12 (c)) were low priority for Phase 1[A] and would not be monitored directly. Opportunities with larger turbine arrays could be more relevant and possible in future phases of the project" (Rollings et al. 2016b). Therefore, the risk of displacement was considered retired for the operational stage of Phase 1A (Marine Scotland 2016).

**Conclusion:** Following the completion of the EIA, consent for Phase 1, and development of the PEMP, the risk of displacement to marine mammals, birds, and basking sharks was retired for operation of Phase 1A with no required monitoring. Mitigation and management measures were required for the construction of Phase 1A.

**Summary of risk retirement:**

DEFINE RISK

- Risk of displacement to marine mammals, birds, and basking sharks was identified and considered in the EIA.

EXAMINE EXISTING DATA

- A comprehensive desktop review of existing literature was carried out.

COLLECT ADDITIONAL DATA

- Two field surveys were undertaken and baseline underwater acoustic data on marine mammals were collected.
- Monitoring for marine mammals, birds, and basking sharks was not required as part of the operational stage of Phase 1A of the project.

APPLY EXISTING MITIGATION

- No mitigation was required during the operational stage.
- Mitigation and management measures were included during construction of Phase 1A, such as limiting any potential disturbance from vessel activity to seals at haul outs or sensitive areas.

## PACWAVE SOUTH – ELECTROMAGNETIC FIELDS

**Project Description:** Pre-permitted, open ocean wave energy test facility off the coast of Oregon, US (Figure 6.9) with capacity to test up to 20 WECs in four berths and an installed capacity not to exceed 20 MW. Each berth will include WECs, umbilical cables hooked up to subsea connectors, and subsea cables (three conductor alternating current cables, bundled and estimated to have a rated capacity of up to 36 kV) to shore (BOEM 2021; FERC 2021; Oregon State University 2019a).

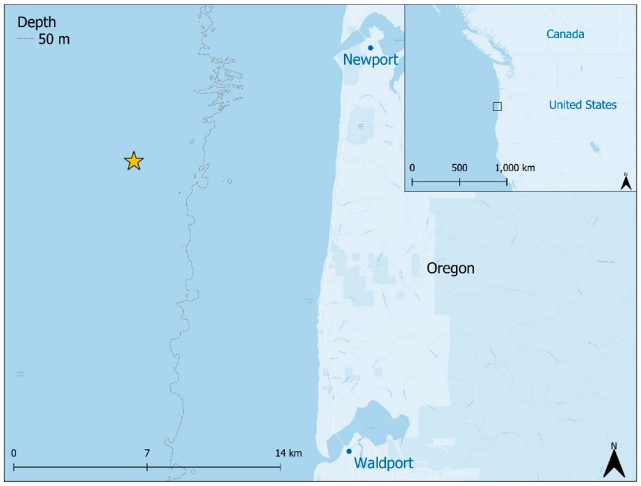



**Figure 6.9.** Location of the PacWave South test site in Oregon, United States (yellow star).

**Stressor-receptor interaction:** Impact of EMFs from cables on fish and invertebrates.

**Pathway to risk retirement:** Research studies and modeling results on EMF emissions were examined to inform concerns on EMFs from cables (Oregon State University 2019b). In particular, a key study commissioned by the Bureau of Ocean Energy Management (BOEM) found no response or biologically significant differences from fish or invertebrates around energized cables and controls (Love et al. 2016) and a summary of the state of the science noted that while species can detect or respond to EMF from subsea cables, EMFs from MRE devices and cables have not been found to negatively impact species, especially for small-scale developments (Gill 2016). These studies informed discussions around potential impacts by the PacWave Collaborative Workgroup, made up of regulatory agencies and other key stakeholders (Freeman et al. 2022).

Although EMF emissions at the site are expected to be low, the power export cables will be buried 1-2 m below the seafloor, or where burial is not possible for the electrical infrastructure (subsea cables, umbilical, subsea

connectors, etc.) shielding and armoring will be used to separate sensitive marine species from emissions (Oregon State University 2019b). In addition, a Finding of No Significant Impact determination was made based on the Environmental Assessment for the PacWave South project as a whole (Department of Energy 2021).

**Conclusion:** Concerns about impacts of EMF from cables were removed based on research studies (Freeman et al. 2022) and the ability to accurately model EMFs (Oregon State University 2019b). Despite finding no significant risk, management measures were applied to limit EMF exposure to the immediate area around cables and other electrical infrastructure (Oregon State University 2019b). An EMF monitoring plan was developed to address uncertainty about EMFs from WECs, which includes modeling EMF emissions, validating these with field measurements from deployed WECs, and reporting exceedances of established thresholds (Oregon State University 2019b, 2019c).

**Summary of risk retirement:**

### DEFINE RISK

- Cables from WECs present a potential risk of EMFs on fish and invertebrates that may be present in the area.

### EXAMINE EXISTING DATA

- Key studies (Gill 2016; Love et al. 2016) informed discussions by the PacWave Collaborative Workgroup, which over time diminished concern about EMF effects from cables on marine life.

### COLLECT ADDITIONAL DATA

- Not required for risk assessment.

### APPLY EXISTING MITIGATION

- Burying or shielding of cables, umbilical, and other electrical infrastructure to minimize EMF exposure. Follow EMF monitoring plan.

## MARINE CURRENT TURBINES, SEAGEN – COLLISION RISK

*Contributed by Ian Hutchison, Shane Quill, and Jennifer Fox (Aquatera Ltd.)*

**Project Description:** Marine Current Turbines Ltd. (MCT) SeaGen project in the Narrows of Strangford Lough, Northern Ireland (Figure 6.10) consisted of a tidal energy converter with twin 16 m diameter rotors supported on a cross beam that was mounted on a pile-driven monopile, with a total installed capacity of 1.2 MW. The project was consented in 2006, operational starting in 2008, and decommissioned in 2015, with final removal of the structures in 2019.

**Stressor-receptor interaction:** Risk of collision for harbor porpoise (*Phocoena phocoena*) and local breeding harbor seal population (*Phoca vitulina*).

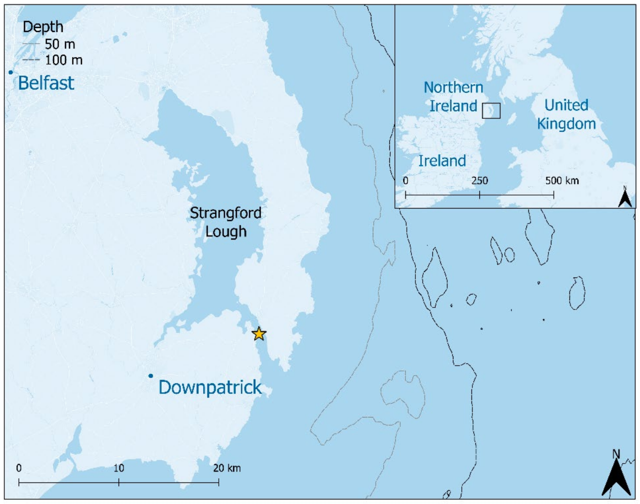



**Figure 6.10.** Location of the SeaGen project in the Narrows of Strangford Lough, Northern Ireland (yellow star).

**Pathway to risk retirement:** License conditions required the development of an Environmental Monitoring Programme. Collision risk was identified as a primary concern and a number of mitigation and monitoring measures were prescribed in the Environmental Monitoring Programme (Keenan et al. 2011), including:

- A system of active acoustic monitoring which detected marine mammals within 200 m of the rotors and allowed precautionary shutdown of the turbine;
- Carcass surveys and post-mortem evaluation of all strandings;
- Pile-based, incidental marine mammal observations carried out between July 2008 and August 2009;
- Seal telemetry studies to track individual harbor seals using GPS phone tags;
- Shore-based visual observations of marine mammals in the Narrows around the turbine site; and
- Acoustic monitoring of harbor porpoise activity in the Narrows using passive acoustic monitoring.

Baseline data were collected starting in April 2005 before installation and formed the basis of an Environmental Baseline Report, against which all future monitoring during installation, commissioning, and decommissioning could be compared (Keenan et al. 2011). Post-installation monitoring results were evaluated regularly to assure that any impact of SeaGen on the marine environment could be detected at an early stage. Using an adaptive management approach, the post-installation monitoring data collected provided evidence to support reduction in mitigation requirements (Keenan et al.

2011). In particular, as understanding of the environmental effects of SeaGen grew, the precautionary shutdown distance was gradually reduced from 200 m to 100 m, and eventually to less than 30 m (Savidge et al. 2014). Although the complete removal of the shutdown protocol was authorized, along with fine-scale monitoring around the turbine blades using a new multibeam sonar system, it was not able to be implemented before the device ceased operation in 2015.

**Conclusion:** The continual analysis of the data collected through the Environmental Monitoring Programme allowed for adaptive management to be applied, and the mitigation requirements around the precautionary shutdown distance to be reduced. While the SeaGen project applied these novel mitigation and monitoring measures, the device ceased operation prior to these being removed and collision risk being retired.

**Summary of risk retirement:**

DEFINE RISK

- Potential for collision of harbor porpoise and harbor seals with turbine blades causing disturbance, injury, or death.

EXAMINE EXISTING DATA

- An EIA was completed in June 2005 with the production of an Environmental Statement. A number of existing datasets were examined during the EIA.

COLLECT ADDITIONAL DATA

- A baseline marine mammals observation survey was carried out for harbor seals (Davison & Mallows 2005).
- To answer key questions about marine mammals, the Environmental Monitoring Programme included a number of post-installation monitoring measures such as carcass surveys and post-mortem stranding evaluations, marine mammal observations, seal telemetry studies, and acoustic monitoring.

APPLY EXISTING MITIGATION

- No existing mitigation measures required.

TEST NOVEL MITIGATION

- A novel mitigation system was used to detect marine mammals within 200 m of the rotors to trigger precautionary shutdowns of the turbine and reduce collision risk. The requirement was reduced to 100 m, then and 50 m. Removal of the precautionary shutdown was approved, but was not implemented before operation ceased in 2015.

## 6.2. ADAPTIVE MANAGEMENT

AM is another approach used to aid consenting processes for MRE. AM is an iterative process to decrease uncertainty by conducting environmental monitoring that provides data and information to address specific questions and to inform management decisions on monitoring (Le Lièvre 2020). This approach can aid MRE development by:

- Navigating consenting processes and advancing projects while managing environmental effects with high levels of uncertainty;
- Contributing information to fill knowledge gaps and increase scientific understanding through data collection and learning while doing;
- Aiding evaluation of monitoring and mitigation effectiveness; and
- Providing new information that can lead to risk retirement for stressor-receptor interactions to benefit future MRE developments and support consenting processes (Le Lièvre 2020).

AM may not be well suited to use in situations where the priority is to protect sensitive species, habitats, or resources rather than to address uncertainty, inform development, and enable deployment and adaptability of monitoring requirements, as AM allows for the possibility of failure or potential negative environmental impacts.

Limited guidance is available for applying AM specifically for MRE, though some examples exist. The Welsh government has developed guidance for AM, including for project-level AM and multi-phase projects (Natural Resources Wales 2024). Examples of MRE projects that have used AM approaches are highlighted in Section 6.2.2.

For AM to be effective for MRE, Le Lièvre (2020) provided recommendations which include the need to:

- Develop implementation guidance by responsible government bodies to provide both a common understanding of AM and guide AM plan design for larger-scale MRE projects;
- Produce guidance documents that specify when AM should be used and what elements should be included;
- Identify resources available (time, funds, etc.) and how best to reduce uncertainty via discussions between regulators and developers; and

- Create mechanisms to minimize undue financial risks for developers pursuing an AM approach, while taking into account environmental protection and consistency of applying the precautionary principle.

## 6.2.1. MANAGEMENT MEASURES

When the priority is protecting the environment and avoiding unacceptable effects, the mitigation hierarchy can be used in conjunction with AM as a precautionary approach to decision-making and development (Elliott et al. 2019; Le Lièvre 2020). If uncertainty, data gaps, or flaws in monitoring design arise during application of an AM approach for MRE projects, the mitigation hierarchy offers options to avoid, minimize, mitigate, and/or restore/compensate for any negative effects with a goal to reduce and mitigate impacts to acceptable levels. However, it should be noted that using such a cautionary approach is likely to hinder the opportunity for learning and reducing uncertainty that is enabled with AM. More information on the mitigation hierarchy can be found in Le Lièvre (2020).

When risks are not well understood, remain uncertain, or a more cautious approach is needed, robust management measures can create greater certainty until data gaps can be filled and an acceptable level of risk is defined, at which time the need for such management measures can be re-evaluated. OES-Environmental created the management measures tool to provide information on management (or mitigation) measures to support the deployment of MRE devices. This tool is available to aid regulators, advisors, developers, and consultants in identifying ways to mitigate possible negative impacts, based on actions that have been used in past or current MRE projects. Management measures that have been used are documented so that each new MRE project need not develop new measures but can learn from others addressing a similar concern. Figure 6.11 shows an example from the tool of a management measure for underwater noise. This tool and the mitigation hierarchy can help projects move forward while managing uncertainty, or until a risk can be retired.

## 6.2.2. ADAPTIVE MANAGEMENT CASE STUDIES

AM has been used across the MRE industry to help projects move forward in the face of uncertainty, including addressing concerns around scaling up from single devices to larger arrays. Two case studies of AM applications in MRE developments are highlighted below. The following case studies were first presented in Le Lièvre (2020) where more information can be found on each project; this section provides updates on their AM approaches.

### ORPC RIVGEN® POWER SYSTEM

The Igiugig Village Council (IVC) has an MRE project in the Kvichak River (Alaska, US; Figure 6.12) where the Ocean Renewable Power Company, Inc. (ORPC) has deployed their RivGen® Power System to provide electricity to the native Village of Igiugig (Igiugig Tribal

| Technology | Project Phase | Stressor | Receptor | Management Measure | Advantages | Challenges | Project Documents |
|---|---|---|---|---|---|---|---|
| Wave, Tidal | Operation & Maintenance | **Underwater noise** The potential effects from underwater noise generated by wave and tidal energy converters. | **Marine Mammals** | **Monitoring** Measure noise generated by device(s) during operation to better understand the potential effects on sensitive species. | Measured noise levels can be correlated with threshold values of relevant species and baseline noise levels of the site to determine impact and need for adaptive management measures. | Can be complex and costly to undertake this type of monitoring in high energy environments. Data and analysis have requirement for acoustic experts. | **SAE Renewables 2011, Aquamarine Power Ltd 2011, Orbital Marine Power 2014, Minesto 2016, Xodus AURORA 2010, European Marine Energy Centre (EMEC) 2019, ScottishPower Renewables 2010, Davison and Mallows 2005, McGrath 2013, Royal Haskoning 2012, Orbital Marine Power 2018, Atlantis Resources Corporation at EMEC, Oyster 800 at EMEC, Minesto Holyhead Deep - Non-grid connected DG500, HS1000 at EMEC, EMEC Billia Croo Grid-Connected Wave Test Site, Sound of Islay Demonstration Tidal Array, Strangford Lough - MCT (SeaGen), Fair Head Tidal Array, Oyster 800 at EMEC, Orbital Marine Power O2 at EMEC** |

**Figure 6.11.** Example of a management measure for underwater noise. The management measures tool offers information on measures used in past or current marine renewable energy projects such as the technology, project phase (installation, operation and maintenance, or decommissioning), stressor and receptor, advantages and challenges, and references to project documents where more information on the measure can be found.

Village Council 2024). The first RivGen® turbine was deployed and tested in 2014 and again in 2015. After securing a Pilot License from the Federal Energy Regulatory Commission (FERC) for a phased approach to deploy two RivGen® turbines (35 kW capacity each) (FERC 2019), the first RivGen® was deployed in 2019 and the second RivGen® was deployed in 2023.

The Kvichak River is home to one of the largest sockeye salmon (*Oncorhynchus nerka*) runs in the world (Fair 2003) and as such, there is a robust fish monitoring plan and resulting AM plan (ORPC 2018). Data collected from underwater video cameras used to monitor fish interaction around an initial turbine deployment in 2015 showed no injuries or behavioral changes to adult salmon during their priority migratory periods (see Chapter 2). These preliminary data provided regulators with confidence to complete the FERC licensing process and pursue an AM approach with the IVC to address remaining fish passage uncertainties specifically associated with the salmon smolt (juvenile) out-migration. The AM Plan that was developed built on ORPC's successful implementation of a similar plan for their Cobscook Bay Tidal Energy Project in Maine, US.

The AM approach and associated monitoring provide data on device interactions with smolt and adult sockeye salmon. In addition, ORPC works with an AM Team made up of regulators and resource managers from federal agencies and Alaska state agencies, as well as technical resource experts from universities and national labs. The AM Team is the mechanism for discussing monitoring requirements based on data collected and findings, and for decision-making, including any changes to the monitoring approach. For example, after undertaking monitoring for several years with no documented collisions and no evidence of impact to adult sockeye salmon, the adult salmon monitoring requirement was removed in 2022 in consultation with the AM Team and in accordance with the annual Alaska Department of Fish and Game Fish Habitat Permit issued for 2022/2023 (Alaska Department of Fish and Game 2022). The risk of project impact to adult salmon has been retired (Alaska Department of Fish and Game 2022). However, the IVC, ORPC, and the AM Team continue to monitor and assess project operations during the smolt out-migration.

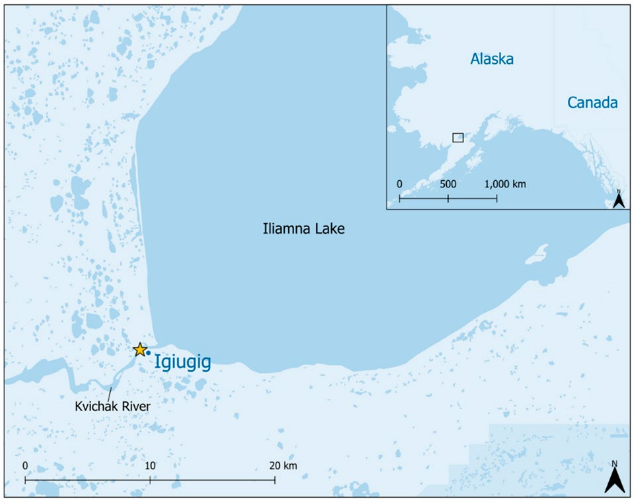



**Figure 6.12.** Location of the Ocean Renewable Power Company's RivGen® Power System near the native Village of Igiugig in Alaska, United States (yellow star).

The AM approach has allowed the IVC to operate under a FERC Pilot License and demonstrate the project's minimal impact on marine animals and the environment, as well as to deploy ORPC devices while continuing to collect data to further understanding of interactions between smolt and the RivGen® and inform monitoring requirements.

## NOVA INNOVATION SHETLAND TIDAL ARRAY

*Contributed by Kate Smith (Nova Innovation)*

Nova Innovation's Shetland Tidal Array in Bluemull Sound, Scotland (Figure 6.5) was the world's first offshore tidal array to supply electricity to the grid, with the deployment of three Nova Innovation M100 devices (installed capacity of 300 kW) in 2016 and 2017. The next phase involved the installation of one of Nova Innovation's "next-generation" direct drive M100-D turbines in August 2020 followed by two more in January 2023, taking the six-turbine array capacity to 600 kW.

Throughout the lifetime of the Shetland Tidal Array, an AM approach has allowed Nova Innovation to work closely with regulators and stakeholders to continuously review and update monitoring objectives and methodologies, as documented in the PEMP. The first PEMP was approved in 2015, with six further versions issued to date, the most recent being Smith (2024).

Following the award of project licenses for the extended six-turbine array but before developing detailed monitoring methodologies, monitoring principles and objectives were agreed upon between Nova Innovation and Marine Scotland as well as NatureScot and other stakeholders in

2018. This non-statutory step in the process was important to collectively agree on the basis for building the detail of the monitoring program so that it was fit-for-purpose and proportionate. The monitoring objectives were, and continue to be, focused on gathering data to improve understanding for collision risk between tidal turbines and marine wildlife.

Until 2023, land-based bird and mammal surveys had been a part of the PEMP, alongside monitoring of subsea nearfield interactions between marine wildlife and the turbines using turbine-mounted cameras. Starting in 2010, land-based surveys were used to gather data on the presence, abundance, and behavior of marine birds and mammals in Bluemull Sound prior to the installation of any turbines. In March 2020, Marine Scotland approved changes to the methodology proposed by Nova Innovation to narrow the focus of the surveys to gather more detailed information on marine birds and mammals within the array area, following trials of the new methods.

In 2023, Nova Innovation set out the case for ceasing the land-based surveys altogether, based on the following rationale:

1. With the exception of European shag (*Gulosus aristotelis*) and black guillemot (*Cepphus grylle*), marine birds and mammals were consistently recorded infrequently and/or in low numbers in the surveys, indicating very low risk of nearfield encounters with the turbines (Brown 2021; Smith 2022, 2023; Smith et al. 2021).

2. The turbine-mounted cameras used to monitor nearfield subsea interactions between marine wildlife and the turbines have been shown to be highly effective (Smith 2023; Smith et al. 2022).

3. Continuing the land-based surveys would be unlikely to provide any new insights into the nature and frequency of nearfield interactions between marine mammals or diving birds and the turbines or improve understanding for collision risk. To continue with the surveys would be disproportionate to the risk and their benefit.

Marine Scotland, in consultation with NatureScot, approved this request and the surveys ceased in July 2023. This and other changes to the PEMP since 2015 reflect the adaptive nature of the monitoring program, which was adjusted to be proportionate and fit-for-purpose in meeting the specified monitoring objectives.

## 6.3. MARINE SPATIAL PLANNING

In the marine environment, there are a plethora of existing uses and pressure for new marine sectors, such as MRE, to join an already busy space. MSP is a future-oriented approach that accounts for uses of ocean space, identifies potential overlaps (both conflicts or opportunities for co-existence), and manages a multitude of uses based on policy objectives. The most widely used definition of MSP is a "public process of analyzing and allocating the spatial and temporal distributions of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process" (Ehler 2014; Ehler & Douvere 2009). MSP should be guided by science and be a strategic, iterative, and adaptive process that includes significant participation from marine users and stakeholders (Morf et al. 2019; O'Hagan 2020).

MSP can be used to create a strategic-level guide that provides a vision to help manage different activities that may occur in the same space or time and to achieve policy-level goals (O'Hagan 2020). Strategically, MSP can identify suitable areas for MRE development, particularly ones with low potential for conflicts with existing uses or with high potential for co-use. This includes areas where MRE resources are viable and align with other important factors to consider for MRE (e.g., distance from port/docks, local supply chain, bathymetry, benthic habitat, presence of endangered species, etc.) as well as where conflict with other marine activities and sectors can be reduced (Quero García et al. 2020). MSP can aid MRE on a project level by providing information for consenting processes and assisting with project-scale decision-making, such as siting and helping to facilitate co-location (sharing of space and resources) of marine activities by designating or identifying areas of complementary use (Salvador & Ribeiro 2023). Finding opportunities for co-location based on uses that may overlap and can be integrated based on their use in time and space will become increasingly important; co-location of MRE and offshore wind or MRE and aquaculture are good examples. For example, there is potential for MRE to provide power to aquaculture operations creating low-carbon energy solutions for the aquaculture industry, while the aquaculture industry can provide a stable and commercial demand for the energy produced by MRE (Freeman et al. 2022; LiVecchi et al. 2019).

Several factors have been identified as limiting the use of MSP for MRE, such as lack of clear objectives; knowledge gaps for environmental, economic, social, and political impacts of MRE; data needs to inform MSP development and associated tools to aid implementation; and adequate resources to carry out MSP including financial and human resources (O'Hagan 2020). Other needs include making MSP participatory to actively involve stakeholders in the development process and including practical measures so MSP can streamline consenting. To progress the use of MSP for MRE, it will be important to identify how specific needs for MRE development change based on scale (single devices to arrays) and purpose (small developments for remote or off-grid communities to large-scale arrays for national grid utility power), and assure that these differences are addressed in planning processes. Additionally, incorporating MRE in energy policies and renewable energy goals will create an incentive to plan for and develop MRE, which in turn can help to advance the use of MSP for MRE at a strategic level (Quero García et al. 2020).

Application of MSP is growing worldwide with over 100 countries/territories estimated to have some form of MSP in various stages of implementation; MSP has been increasingly used to achieve sustainable development and growth of blue economies, while considering environmental needs (Intergovernmental Oceanographic Commission 2022; Marine Spatial Planning Global 2022). MSP is employed in several OES-Environmental countries, with a few incorporating MRE into these processes (see online supplementary material). Figure 6.13 provides a summary of OES-Environmental countries and where they are in MSP development.

## 6.3.1. CASE STUDIES OF MSP FOR MRE

To date, there are few examples of MSP that have helped advance MRE. Several case studies are highlighted below to show how MSP has aided MRE development. As MSP continues to advance in many countries, and more MRE devices are deployed in areas with marine spatial plans, it will be important to continue to share examples and evaluate how MSP affects different maritime sectors, including MRE.

### ORKNEY ISLAND MARINE SPATIAL PLAN

*Contributed by Shane Quill and Ian Hutchison (Aquatera Ltd.)*

Marine Scotland, Orkney Islands Council, and the Highland Council developed the pilot Pentland Firth and Orkney Waters Marine Spatial Plan (Plan) (Marine Scotland & The Highland Council 2016), as an integrated planning policy framework to guide marine development, activities, and management decisions, while also ensuring protection of the marine environment. The Plan is used by the Marine Scotland Licensing Operations Team (MS-LOT) as part of the determination process for marine licensing and consent applications within the Pentland Firth and Orkney Waters. The Highland Council and Orkney Islands Council adopted the pilot Plan as non-statutory planning guidance.

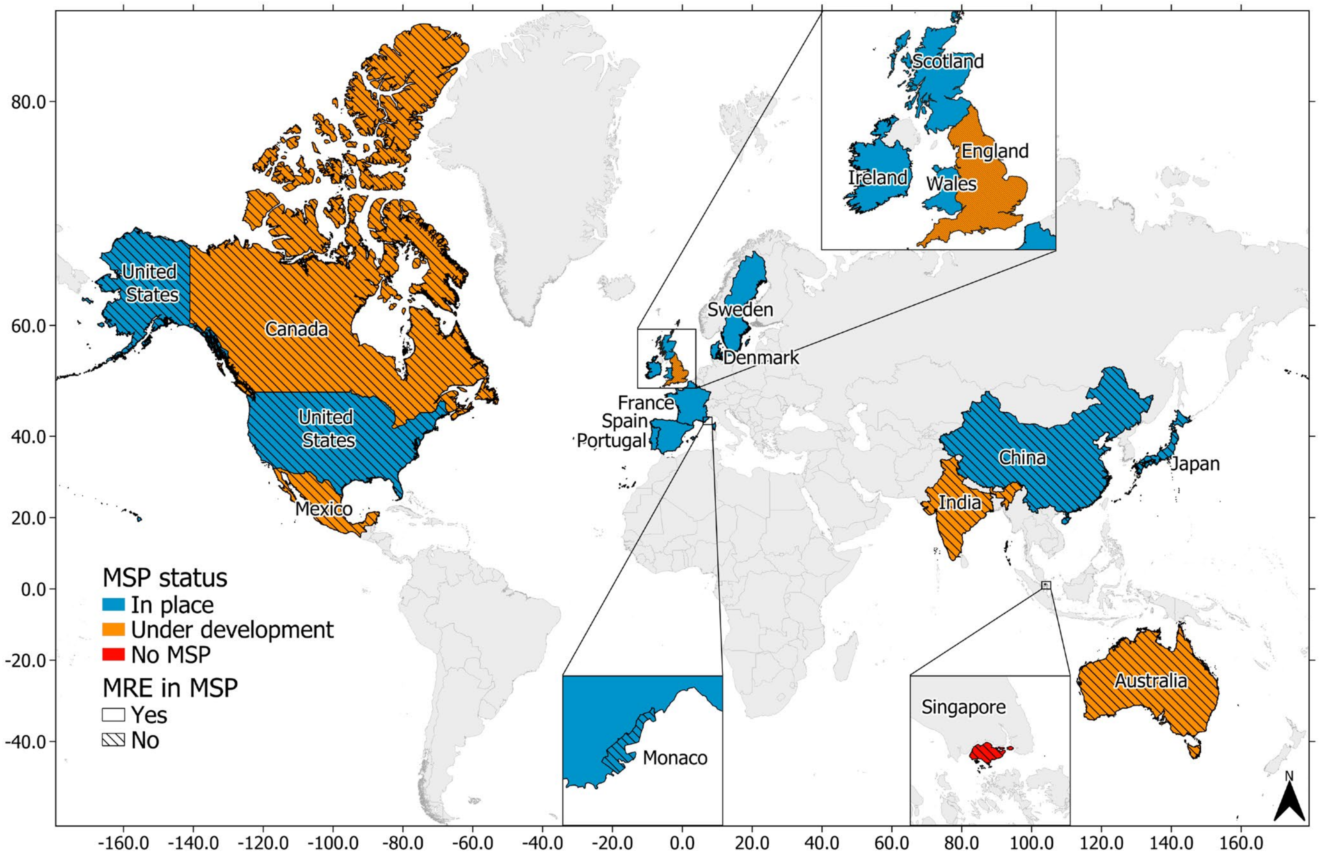



**Figure 6.13.** Summary of marine spatial planning (MSP) in Ocean Energy Systems (OES)-Environmental countries, with MSP processes specifically including marine renewable energy (MRE). Several countries (e.g., France, England, Mexico, Monaco, United States) only have MSP in place within certain areas, such as regionally or at the state level.

Sustainable growth of the sector and co-existence with other marine users is clearly stated as a key goal within the Plan. The Plan contains several Sectoral Policies that are used to guide development and aid in the determination of license and consent applications. Sectoral Policy 4: Renewable Energy Generation acknowledges that the Pentland Firth and Orkney Waters area has some of the most abundant natural MRE and offshore wind resources in the UK and that the sustainable development of renewable energy projects in the area has the potential to help the UK meet its strategic climate change goals.

The Plan acknowledged that the Pentland Firth and Orkney Waters area was designated as a Marine Energy Park in 2012, within which it was hoped that the commercialization of MRE technologies can be promoted and accelerated. There have been more deployments of MRE technologies in the Pentland Firth and Orkney Waters area than in any other region worldwide, primarily due to the presence of EMEC.

The Plan recognized that knowledge gaps exist for potential environmental effects of MRE projects and that there is a need to undertake environmental monitoring and research to gather relevant evidence to inform the decision-making process. The Plan confirmed support for MRE and offshore wind developments, and encouraged their feasibility in appropriate areas as identified through the Sectoral Marine Plan process. The Plan referred to the existing Regional Locational Guidance and the importance of early and effective engagement with relevant affected stakeholders, as well as avoidance or minimization of adverse impacts or mitigation of any unavoidable adverse impacts.

## OREGON TERRITORIAL SEA PLAN

The state of Oregon developed a Territorial Sea Plan in 1994 (Oregon Coastal Management Program 2023). The plan covers a three-nautical mile strip of the coastline in state waters, guides federal and state actions in managing uses and activities of the space, and builds on an earlier Ocean Plan (Oregon Coastal Management Program 1991) to cover the entire 200 nautical miles exclusive economic zone off the Oregon coast (State of Oregon 1994). Developing the Territorial Sea Plan included significant stakeholder engagement activities, geospatial analysis, and environmental considerations to designate areas for siting specific activities while minimizing conflict and adverse impacts.

Beginning in 2009 and updated in 2019, MRE development was included as Part 5 of the plan (State of Oregon 2023). The requirements for siting MRE and offshore wind projects in state waters are described with the goal of protecting ocean resources, ecosystems, and coastal communities. Specific areas are noted in the plan that range from not allowing MRE development (Renewable Energy Exclusion Area) to areas with minimal conflict between resources and uses (Renewable Energy Facility Suitability Study Area) or areas authorized for MRE development testing and research (Renewable Energy Permit Areas).

The Territorial Sea Plan has been used in decision-making for MRE policies (Brandt 2021), for consistency for federal renewable energy projects—for example, as a consideration for development of the cable route for PacWave South (PacWave 2019), and for planning state water components of offshore wind energy lease areas (BOEM 2020).

## ZONES TO ENHANCE OR TEST MRE

Designated marine zones and areas prescribed for testing technologies can be considered MSP-adjacent efforts and have been used to advance sectors like MRE. While these exists in several countries around the world, two examples for MRE include Portugal's technological free zones (TFZs) and Australia's Blue Economy Zones (BEZs).

### Portugal Technological Free Zones

*Contributed by Inês Machado (WavEc)*

TFZs are part of a larger government initiative working toward further development of innovation by creating safe spaces (or "sandboxes") that allow testing and experimentation, and encourage the offshore development of renewable technology (Decreto-Lei n.º 67/2021; Portugal Digital 2022). The Decree-Law nº 15/2022 (2022) established the legal framework to implement renewable energy-related TFZs. The primary objective is to promote research, demonstration, and testing of energy-related projects in a real-world environment. TFZs are managed directly by the Directorate General of Energy and Geology, or through concessions awarded by a competitive process.

Portugal's Ordinance 298/2023 (2023) approved a TFZ near Viana do Castelo focused on offshore and nearshore renewable energies to foster innovation and the development of projects for producing electrical energy from MRE and offshore wind energy. This site is located 18 km offshore of Viana do Castelo and is composed of a 7.63 km² area designated for pilot projects to test and experiment with wave energy and offshore wind energy technologies. As a part of the Ordinance (Portaria n.º 298/2023), a public consultation process is required with stakeholders.

### Australia Blue Economy Zones

*Contributed by Irene Penesis and Chris Frid (Blue Economy Cooperative Research Centre)*

Funded in part by the Australian Commonwealth government, the Blue Economy Cooperative Research Centre has been exploring implementing BEZs in Australia since 2019. BEZs are offshore (i.e., beyond 3 nm) ocean areas designated for research on emerging blue economy industries, including renewable energy (MRE and offshore wind) and aquaculture, with a focus on sustainability and advancing innovation (Blue Economy Cooperative Research Centre 2022).

To date, one BEZ has been designated in the Bass Strait, between Tasmania and the Australian mainland. Initial environmental and resource assessments have been undertaken, and plans for deployments of aquaculture, MRE, and offshore wind infrastructure trials are advancing. During the planning and development phase of this project, MSP was used to help identify potential areas for the BEZ. A research trial site within the area was selected based on stakeholder input and baseline monitoring data (Blue Economy Cooperative Research Centre 2022).

## 6.4.
## ADDITIONAL TOOLS AND RESOURCES TO AID CONSENTING

There are many additional tools and resources to aid MRE development, some of which are described in this section. Two European Union-funded projects (Wave Energy in Southern Europe [WESE; Portugal and Spain; 2018 – 2021] and Streamlining the Assessment of Environmental Effects of Wave Energy [SAFEWave; France, Ireland, Portugal, and Spain; 2018 – 2024]) have worked toward developing research, resources, and tools to aid consenting and increase understanding on environmental effects of WECs. The first tool developed under WESE is an ecological risk assessment (ERA) framework to identify risks from WECs. Available as an online tool, WEC-ERA, was built for scientists, managers, and decision-makers to use during EIAs for wave energy developments (Galparsoro et al. 2021). The second tool, VAPEM, an environmental assessment and MSP tool, is used to help manage marine activities, incorporate ecosystem services, and identify suitable development opportunities. In addition, the SAFEWave project identified risk-based approaches to aid MRE consenting and developed a risk-based framework (Verling et al. 2023). Verling et al. (2023) identify commonalities and variations between risk-based approaches relevant to MRE, including OES-Environmental's risk retirement process (see Section 6.1) and Scotland's survey-deploy-monitor approach (Marine Scotland 2018; Scottish Government 2023). They use key elements of each to create a risk-based framework for uptake by authorities in implementing consenting processes. The SAFEWave's risk-based framework includes four main steps (Figure 6.14) and notes how other approaches for MRE align with it.

In the UK, several tools have been developed to support MRE consenting. In Wales, Information Notes were developed and written by the Ocean Renewables Joint Industry Programme (ORJIP) Ocean Energy and co-produced with the Welsh Science and Evidence Advisory Group for the Welsh Government to support MRE consenting. The Information Notes provide current understanding of the different environmental effects associated with MRE devices from the perspective of a range of stakeholders including regulators, statutory nature conservation bodies, and industry; identify knowledge gaps; and detail how this is applied to consenting MRE in Wales (ORJIP Ocean Energy 2022b). These technical documents address collision risk, underwater noise, electromagnetic fields, changes in habitat, changes in oceanographic systems, entanglement, environmental monitoring, data transferability, and cumulative impact assessment. In Scotland, Marine Scotland published a consenting and licensing manual for MRE and offshore wind (Marine Scotland 2018). This document provides guidance for those involved in consenting and licensing applications in Scottish waters including energy developers, regulators, advisors, and interested stakeholders.

In the US, the Marine Energy Environmental Toolkit for Permitting and Licensing brings together information on environmental, spatial, regulatory, and scientific information for regulators and developers. The toolkit seeks to increase understanding of environmental effects of MRE projects to reduce assessment timelines and costs for projects, for regulators and developers. This project leverages work from the Pacific Northwest National Laboratory (including OES-Environmental and Tethys), the National Renewable Energy Laboratory, Sandia National Laboratories, and FERC.

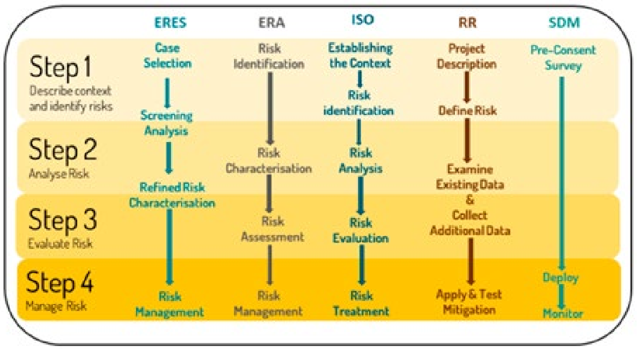



**Figure 6.14.** SAFEWave's risk-based framework for marine renewable energy (MRE) and other approaches used for MRE, including Ocean Energy Systems (OES)-Environmental's risk retirement (RR) process. ERES = Environmental Risk Evaluation System (Copping et al. 2015); ERA = Environmental Risk Assessment framework; ISO = International Organization for Standardization risk assessment techniques from ISO Standard 31010 (International Electrotechnical Commission, 2019b); and SDM = Survey-Deploy-Monitor guidance. Figure from Verling et al. (2023).

## 6.5. RECOMMENDATIONS AND CONCLUSION

Risk retirement and data transferability, AM, and MSP are all methods to help the MRE industry progress and responsibly deploy MRE devices, and in turn increase learning and understanding of environmental effects. These approaches can be used individually or in combination with one another and may be used during different stages of MRE development.

Risk retirement and data transferability can be used at all levels and stages of MRE development. At the strategic level, gaining consensus from regulators and advisors on which stressor-receptor interactions can be retired is important. For developers, consultants, and the broader MRE industry, it is particularly important to understand where additional focus is needed for monitoring and mitigation of identified risks, and where coordinated strategic research can be most effective. At the project level, risk retirement can help differentiate between actual risks and uncertainty versus low-risk interactions that can be retired. As part of risk retirement, it is necessary for developers and their consultants to transfer data from other MRE projects, research studies, or analogous industries to inform projects and retire risks, as this will save time and resources. These processes will help ensure that the approach to consenting is proportionate to the level of uncertainty and risk under consideration, and to reduce unnecessary duplication of effort and resources by applying the wider evidence base. Efforts should be made to use risk retirement to lessen financial burdens and move toward proportionate regulatory requirements. To enhance the use and effectiveness of risk retirement throughout the MRE industry, recommendations include the need to develop best management practices for application; to continue sharing examples—both successes and lessons learned; for regulators and advisors to be willing to apply risk retirement and data transferability in consenting processes; to fund and support research on remaining risks not yet ready for retirement; and to carry out additional research as developments increase to larger-scale arrays.

AM has shown to be a useful approach to aid MRE at the project level, particularly in cases where risks cannot be retired or where uncertainty remains, acting as a flexible, learn-by-doing approach to collect data and adapt monitoring over time. AM provides an attractive option for regulators and advisors to consent MRE developments while still allowing for environmental interactions to be understood and action taken, if needed. For MRE developers to be able to incorporate AM approaches, it will be important to identify available resources (time, funding, etc.) and minimize undue financial risks, while balancing environmental protections. To build on successful applications of AM in the MRE industry and continue its use aiding consenting, MRE-specific implementation guidance is recommended that includes a strategic understanding on the best approaches for applying AM to MRE, how to best reduce uncertainty through discussions between regulators and developers during various project stages, and how best to apply AM to larger-scale MRE developments.

MSP is best used during planning and siting stages to identify suitable locations for MRE development within a multi-user space. MSP can aid in strategic-level planning, but to do so, policy- and decision-makers must be aware of the needs for MRE consenting and development to incorporate them into MSP. These needs will vary based on the purpose of an MRE project (grid-connected, providing power at sea, testing, etc.) and can best be incorporated into MSP processes through expert consultation. MSP may also have project-level benefits, particularly if spatial plans can provide guidance, data, and information to aid MRE siting and consenting, as well as reducing conflicts with other ocean users. Where countries or authorities designate specific zones or areas for MRE development, a coordinated approach to environmental surveys and monitoring can be realized, which may lessen the requirements on project developers. To increase the use of MSP for advancing MRE, recommendations include creating incentives for including MRE in energy policies and renewable energy goals, having clear objectives for MRE as part of MSP including incorporating practical measures to streamline consenting, increasing available data and tools to inform MSP development that include MRE needs and fill knowledge gaps (e.g., environmental, economic, social, and political effects of MRE), and identifying future needs for MRE development based on development scale and applications.

These approaches can be key steps in moving beyond challenges and barriers for MRE projects in the face of regulatory and scientific uncertainty, toward pathways for success. As they become more widely used, more MRE devices may be deployed for small- and large-scale developments and commercial projects, providing opportunities to further increase understanding of environmental effects and working to achieve decarbonization and climate goals. By applying these approaches and sharing lessons learned, the MRE industry and regulatory agencies can navigate consenting processes more efficiently and effectively over time. As countries work to achieve their renewable energy goals, using risk retirement and data transferability, AM, and MSP will help responsibly deploy MRE devices in the marine environment and expedite the scaling up and commercialization of the MRE sector.

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