14.0

Chapter author: Andrea E. Copping

Summary and Path Forward

The 2020 *State of the Science* report collates and presents the current understanding of interactions between marine renewable energy (MRE) systems and the marine environment, with an emphasis on their effects on marine animals, habitats, and oceanographic systems, using publicly available information. The report places this information in context through lessons learned from research studies in the laboratory and in the field, modeling simulations, and deployments; monitoring around demonstration, pilot, and small commercial MRE projects; identifies gaps in knowledge and makes recommendations for filling those gaps. In addition, strategies for moving toward a consistent and effective consenting or permitting (hereafter consenting) process and management of the potential effects of MRE development are highlighted. The value of the evidence presented in this report will be realized through its application to consenting processes to accelerate the responsible deployment of further MRE devices and arrays. The status and recommendations from each of the priority interactions between MRE devices and the environment are summarized here, and the management strategies for facilitating development are discussed. Finally, a path forward toward commercial MRE development is explored.

14.1. SUMMARY OF FINDINGS

In addition to the detailed reporting and analyses of each set of stressor-receptor interactions, we have attempted to document the continuing level of perceived risk for each interaction. For simplicity, we define risk as the interaction of the likelihood (probability) of an event occurring with the consequences of that event. This documentation takes the form of a simple dashboard and guide for how the level of risk for each interaction might be further understood and lowered. The dashboard consists of an old-fashioned odometer-type dial that uses green to indicate a well understood and relatively low risk from a stressor to yellow and red that indicate increased levels of risk. The dashboard also features a bar graph to indicate what avenues of investigation and sharing are needed to further understand and lower the risk from that stressor (Figure 14.1). These avenues include

- increased sharing of available information
- improved modeling of the interaction
- monitoring data needed to validate models
- new research needed.

Each dashboard represents our estimate of the risk using the best available information collated in this report for each stressor and is broadly proportional to the other stressors. However, it is important to understand that certain risks may be perceived to be high, but may be found to be lower, as more knowledge is acquired. We hope the dashboards will prove valuable as a simple means of visualizing the perceived level of risk, and that they may be updated over time as new information becomes available. Only a limited number of operational devices are in the water, ranging from single turbines to small arrays. Because of the current level of MRE development, the levels of perceived risk reported here are associated with small numbers of devices. As commercial-size arrays are developed and occupy larger areas of the sea, the perceptions of risk for certain stressor-receptor interactions may change.

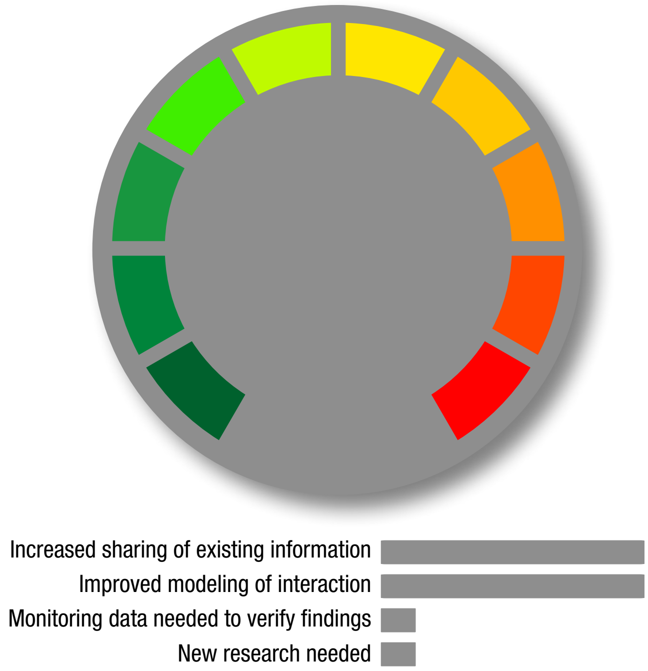

Figure 14.1. Generic version of a dashboard (dial on the top) that demonstrates the broadly understood level of risk for specific stressors, as of 2020, with indication of a pathway forward to further understand and lower the perceived risk of the stressor (bar graph on the bottom). These dashboards were drawn in the style of Copping and Kramer (2017), and updated with information from this report. (Graphic by Robyn Ricks)

The major findings from each of the chapters and topics in this report are summarized in the following sections.

14.1.1. COLLISION RISK FOR ANIMALS AROUND TURBINES

As detailed in Chapter 3 about collision risk, the risk of marine animals colliding with moving parts of tidal and river turbines continues to be the greatest concern for regulators and stakeholders. Among other interactions of concern, this risk has proved to be the most resistant to progressing toward a solution. Considerable effort and resources have gone into modeling, measuring, and observing the potential interactions of marine mammals, fish, and seabirds around turbines; however, fundamental questions remain. One of the greatest barriers to better understanding collision risk stems from the technical challenges related to making observations in the vicinity of turbines in high-energy waters. These observations are particularly challenging because the probability of sightings of marine animals, particularly marine mammals and diving seabirds, is expected to be rare.

Key gaps in knowledge and uncertainty about the potential risk of collision to marine animals remain to be investigated. These gaps include the need for the following:

- determine the probability of a marine animal being struck by a turbine blade while traversing a channel with MRE devices
- determine the likelihood of a collision, based on the characteristics of the turbine blades, the channel morphology, and oceanographic features of the flow
- characterize the seriousness of a blade strike, if it occurs
- understand the impacts on a marine population if individuals are lost as a result of blade strike
- identify sublethal effects of blade strike that may result in significant injury or death at a later time
- assess the ability to scale rates of collision from a single turbine to an array of turbines.

A substantial number of modeling efforts have been carried out to estimate the risk of collision of marine mammals, fish, and birds around turbines. The models have been based on a variety of approaches and geometries, and none of them have been challenged and verified with sufficient post-installation monitoring data to determine which of them best emulate the real world and should be used to estimate potential risk of collision, or whether this is a sensible avenue to pursue for characterizing and quantifying risk. This lack of data continues to hamper estimates of likely collision risk, leading regulators to act conservatively. Models for translating risk to populations based on losses of individuals are commonly used to set regulatory thresholds, but these models have been created to estimate the effects of very different types of risks (such as the risk of entanglement in fishing gear) and have not been applied to potential turbine collisions.

This risk remains relatively high because of the significant uncertainties as well as the very high consequences if a collision occurs (Figure 14.2).

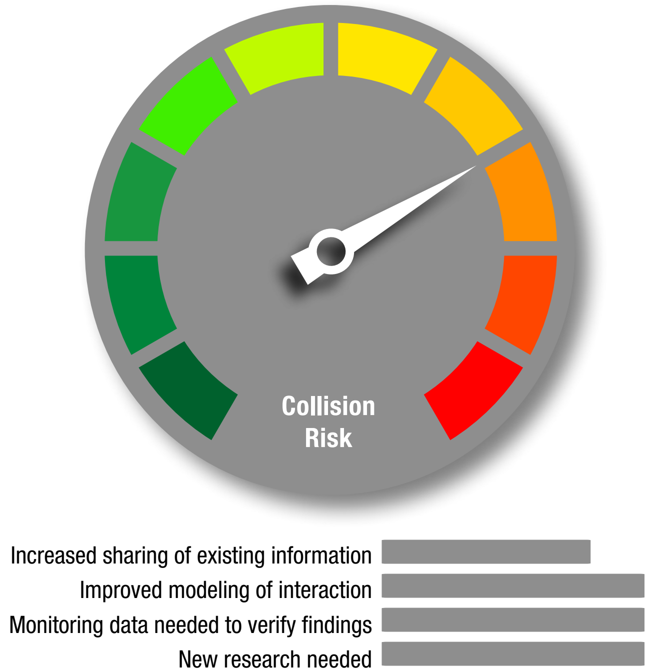

Figure 14.2. Dashboard (dial on the top) that summarizes the broadly understood level of risk that collisions will occur between marine animals and turbines, as of 2020, for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of collision. (Graphic by Robyn Ricks)

14.1.2. UNDERWATER NOISE

Chapter 4, concerning underwater noise, detailed what is known about characterizing underwater noise from MRE devices and estimating how these levels of sound might affect marine animals, especially marine mammals and fishes. Based on the levels of sound that have been measured to date from turbines and wave energy converters (WECs), it appears that sound levels are considerably below those that might be expected to cause physical harm to animal tissues, including those associated with hearing. MRE-generated underwater noise is considered most likely to affect the behavior of marine animals; acoustic pressure is most likely to affect marine mammals and seabirds and perhaps sea turtles (Holt et al. 2009; Jensen et al. 2009; Lesage et al. 1999); while fish are more sensitive to acoustic particle velocities (Popper and Hawkins 2018).

These effects, however, are extremely difficult and costly to investigate, particularly because these intelligent animals adapt and become acclimated to ongoing stimuli (NRC 2003). Research on underwater noise from MRE devices has focused on improving the measurement of MRE device sound emissions and placing those emissions in the context of the ambient soundscapes at existing and planned MRE deployment sites. Measuring sound emissions from MRE devices is challenging because of the high energy of the waters in which devices are deployed; however, the International Electrotechnical Commission Technical Committee 114 standard (IEC TC 114 2019) can be applied to produce accurate measurements. Although few MRE devices have been characterized using this standard, to date all sound emissions have peaked under or near the underwater sound action thresholds for marine mammals (NMFS 2018) or fish (Tetra Tech 2013). The thresholds for underwater noise examined to date consider the likelihood of injury or death to marine mammals; additional thresholds have been developed that also consider lower levels of noise that may disturb or harass marine mammals.

The most critical needs for better understanding the potential effects of underwater noise from MRE devices include the following:

- measuring sound emissions from additional types and models of turbines and WECs across sound frequencies within the hearing range of marine animals
- differentiating between MRE device sounds and ambient sound in the marine environment at MRE sites
- comparing MRE sound emissions to the standards in place in the United States (and any variations accepted in other nations) to determine whether the thresholds are approached or exceeded by particular MRE devices and systems
- observing marine animals around MRE devices when possible, if regulatory thresholds are exceeded
- developing a database of noise signatures from different devices
- developing dose response metrics for behavioral response of marine animals.

This risk is low but some questions remain (Figure 14.3).

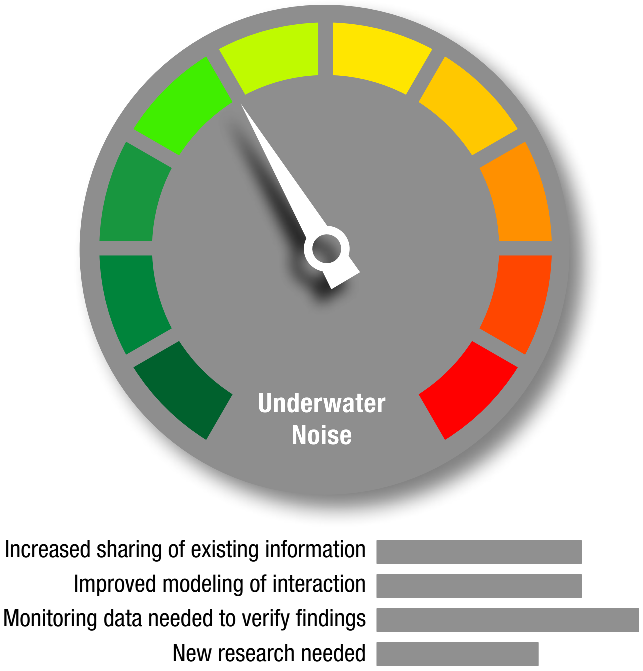

Figure 14.3. Dashboard (dial on the top) that summarizes the broadly understood level of risk from underwater noise from marine renewable energy devices to marine animals, as of 2020, for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of underwater noise. (Graphic by Robyn Ricks)

14.1.3. ELECTROMAGNETIC FIELDS

Chapter 5, about electromagnetic field (EMF) effects on animals, summarized research on the potential effects of MRE power cables and other electrical infrastructure on sensitive marine species. Investigations focused on behavioral, physiological, and developmental/genetic effects. Behavioral investigations have taken place in the laboratory and in the field. While some changes have been noted in sensitive species, none have indicated that crossing EMF at levels typical of MRE-level power cables will significantly alter behavior in a manner likely to be harmful to the individual or the population. Laboratory studies of physiological and developmental changes have been carried out for a wide range of species, many of which are unlikely to encounter MRE cables, but these results are not easily applied in the environment. While it would be easy to dismiss the potential effects of EMFs from cables based on the many cables carrying power in the ocean over many decades, the cumulative effects remain unknown, particularly because future large arrays of MRE devices may be operated in areas already significantly occupied by other EMF sources.

Research and monitoring investigations that will continue to inform this risk include the following:

- developing a reference database that relates power cable configuration, size, and power transmission levels common to MRE cables, to provide EMF output levels
- examining EMF outputs from other underwater infrastructure, such as substations, that will be needed as multiple devices and arrays are deployed in the future
- additional examination of potentially sensitive marine species that are found in the vicinity of MRE project sites for which little research has been done to determine their level of sensitivity to EMF
- better characterizing and modeling of the exact nature of the EMF surrounding cables and other electrical infrastructure as new equipment types are included in MRE development.

Based on research studies, and, in comparison to EMF levels emitted from existing power cables and those associated with offshore wind, this risk can be considered to be relatively low (Figure 14.4).

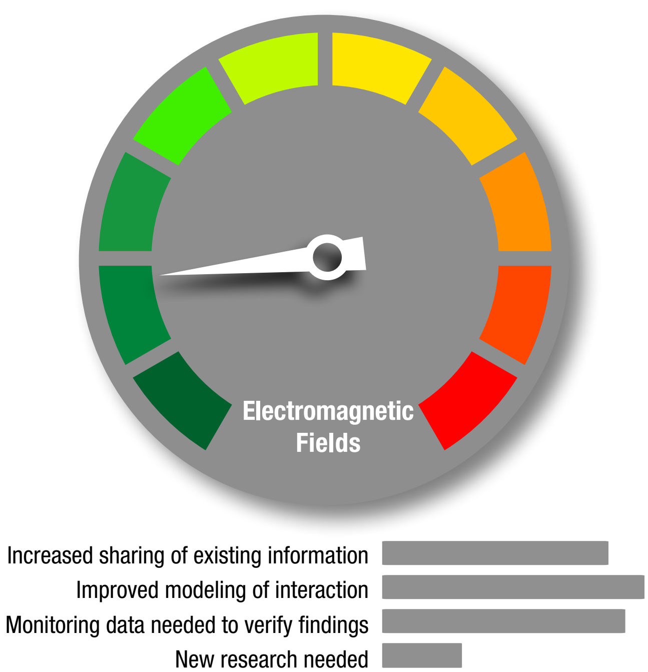

Figure 14.4. Dashboard (dial on the top) that summarizes the broadly understood level of risk from electromagnetic fields (EMFs) from marine renewable energy devices to marine animals, as of 2020 for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of EMFs. (Graphic by Robyn Ricks)

14.1.4. CHANGES IN HABITATS

Chapter 6, concerning changes in habitat, provided insight into the potential effects on benthic and pelagic habitats from the installation and operation of MRE devices, including foundations, anchors, mooring lines, and cables. In addition to changes in habitats, introducing new hard habitats in the form of MRE devices and gear may change the behavior of certain species, especially fishes that are likely to reef around the installations. The footprints of MRE devices and systems, as well as the tendency of marine animals to aggregate around them, does not differ from the effects of other marine installations ranging from navigation and observation buoys, platforms, docks, oil and gas rigs, and piers. These other installations and industries inform us of the potential effects of habitat changes, including the potential for biofouling organisms to give entrée to non-native invasive species in an area.

Research and monitoring investigations that could help resolve the relatively small risks around habitat changes include the following:

- establishing a baseline for the biodiversity and habitat types for each region where MRE devices will be deployed in order to improve the siting of devices and to understand whether changes are taking place over the life of an MRE project
- determining the degree of non-native invasive species penetration into waters and habitats surrounding MRE projects to gauge what possible effect the introduction of new hard habitats might have on the area.

Based on information from analogous offshore industries and the relatively small footprint of MRE foundations, anchors, and mooring lines, this risk can be considered to be low (Figure 14.5). However, the most critical aspect of minimizing harm to habitats is the appropriate siting of MRE projects to avoid all rare or fragile habitat types.

With future expansion of large arrays of MRE devices, the potential to affect common habitats should be revisited.

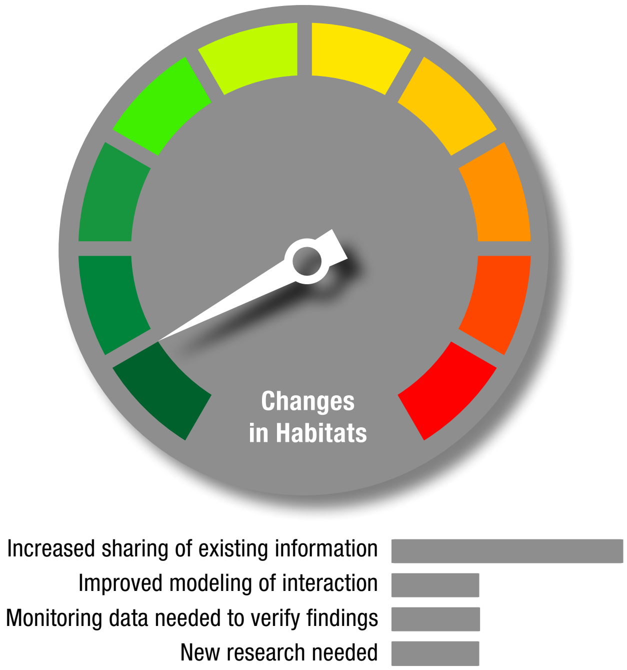

Figure 14.5. Dashboard (dial on the top) that summarizes the broadly understood level of risk from changes in habitats from marine renewable energy devices on marine animals, as of 2020 for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of changes in habitats. (Graphic by Robyn Ricks)

14.1.5. CHANGES IN OCEANOGRAPHIC SYSTEMS

Chapter 7 described the state of knowledge about potential changes in oceanographic systems that could occur as a result of MRE development. Changes in circulation, wave height, and subsequent changes to sediment transport patterns, water quality, and marine food webs are certain to be small for one or two MRE devices, well within the natural variability of the oceanographic systems. Once very large arrays are put in place, the ability to measure these changes and understand their potential ecological consequences will need to be revisited. In the meantime, numerical models allow us to estimate the changes that might occur as large numbers of devices are deployed and operated. To date, the changes estimated using models indicate that they are likely to be localized and revert to background levels within short distances from the devices. The number of devices used in these models to demonstrate change in the environment often exceeds the realistic number that are likely to be consented, based on other concerns such as underwater noise and collision risk.

Research and monitoring that will further resolve the estimates from numerical models include

- collecting monitoring data around operating MRE devices to validate the existing numerical models and to determine that the assumptions are accurate
- improving numerical models to focus on realistic conditions for locations into which MRE devices will be deployed, as well as providing realistic representations of turbines or WECs that include the position in the water column where devices will be deployed
- representing in numerical models the linkages from the potential effects of small numbers of MRE devices to large arrays
- improving these understanding for long-term baseline shifts in oceanographic processes, for example caused by climate change.

Based on modeling studies, this risk can be considered to be low (Figure 14.6).

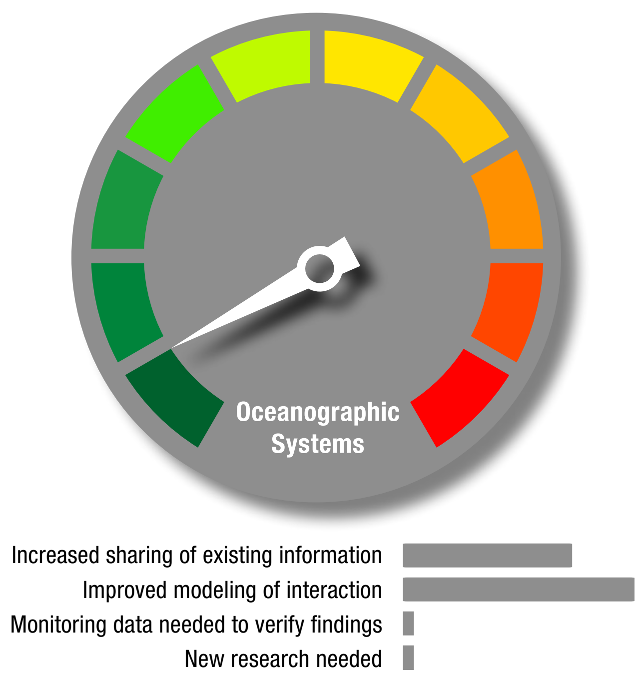

Figure 14.6. Dashboard (dial on the top) that summarizes the broadly understood level of risk from changes in oceanographic systems caused by marine renewable energy devices, as of 2020 for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of changes in oceanographic systems. (Graphic by Robyn Ricks)

14.1.6.
MOORING LINES AND SUBSEA CABLES

Chapter 8 described concerns about potential entrapment or entanglement of large marine species such as marine mammals, sharks and other large fishes, and sea turtles, in mooring lines and cables along the seafloor and in the water column. These concerns are largely based on decades-old issues related to submarine cables laid loosely on the seafloor, entangling great whales (a practice that was soon corrected), and the ongoing risk to animals from abandoned and lost fishing gear and lines. MRE mooring lines have no loose ends, nor is there sufficient slack in the lines to create an ensnaring loop. The overall risk from this stressor is likely very low for MRE, but some stakeholders remain concerned that direct interaction, or secondary collection of derelict fishing gear, could cause harm to large animals.

Research and monitoring that could help further elucidate this risk include

- establishing routine maintenance that includes monitoring of mooring lines for derelict gear and their removal in order to reduce potential secondary entanglement
- better understanding of the diving and swimming behavior of animals that might be at risk to help with siting of MRE development away from dense migratory routes and to determine the depths for placement of draped cables in the water column
- describing the relative scales and interactions of marine animals with lines and cables using field measurements and numerical models, which can form the basis for outreach materials to help stakeholders understand this risk.

Based on studies that examine the scale and mechanisms for entanglement, this risk can be considered to be low (Figure 14.7).

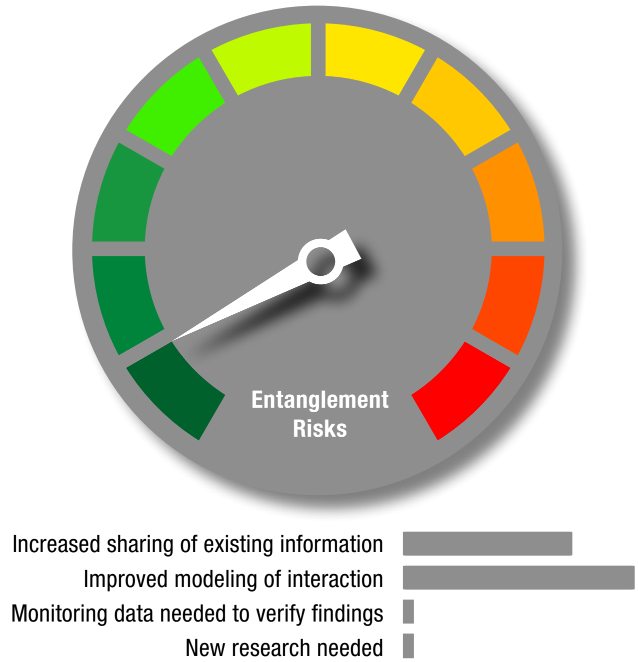

Figure 14.7. Dashboard (dial on the top) that summarizes the broadly understood level of risk to marine animals from mooring lines and cables related to marine renewable energy devices, as of 2020 for small numbers of devices. Risk may vary with larger arrays. The bar graph on the bottom demonstrates a pathway to better understanding and lowering the perceived risk of mooring lines and cables. (Graphic by Robyn Ricks)

14.1.7.
SOCIAL AND ECONOMIC INTERACTIONS

Preparation of environmental assessment documents in most nations requires analysis of the social and economic effects that a proposed MRE project may have on a local area or region. Chapter 9, on social and economic data needs, described the data collection and analysis efforts needed to inform these documents, and also considered the need to track these data throughout the life of the project, to determine whether the estimates are accurate, and to inform future projects. Social and economic effects should be examined at the local level as well as at a larger strategic scale.

Efforts that can assist with standardizing social and economic data collection and analysis efforts, making them more transparent and useful, include

- determining what data are available at the local, regional, and national level to support the performance of both project-specific and strategic analyses
- assessing, through agreements with governments at all levels, what data should be collected and tracked by the MRE project developer and what data should be the purview of governments to better understand the strategic implications of MRE development.

14.1.8. ENVIRONMENTAL MONITORING TECHNOLOGIES AND TECHNIQUES FOR DETECTING INTERACTIONS OF MARINE ANIMALS WITH TURBINES

Chapter 10 of the report delved into the technologies that have been used to detect interactions between marine animals and MRE devices, with an emphasis on the use of existing and emerging technologies to observe and quantify collision risk around turbines. Key instruments that have been used to observe the interactions of marine animals with turbines include passive and active acoustics, as well as optical cameras. Many of these instruments have been mounted and integrated together on platforms, often with data acquisition systems. Challenges in deploying and operating instrument packages to measure animal interactions in the high-energy waters in which tidal and river turbines are deployed include: the need to secure the instrumentation in place either on the seafloor or in the water column; difficulties in operating optical cameras in turbid waters; challenges of controlling biofouling on instrument sensors (particularly optical sensors and lenses); large data mortgages that can be acquired with the use of high-frequency acoustic and optical data collection; the need to operate lights that may change animal behavior for optical image capture in most environments; power management of autonomous integrated packages that rely on batteries, the relatively low densities of animals in fast-moving water; and the cost for developers.

Research and monitoring efforts needed to continue to progress in observing marine animals around turbines include

- establishing collaborative projects among investigators from many nations to develop data collection and analysis methods, particularly for active acoustic data that are prone to interference from ambient conditions at high-energy sites
- pursuing ongoing investigations and trials leading to the standardization of a suite of instruments and instrument packages that have proven to be effective
- continuing the development of strategies to deal with the large quantities of data that are collected and must be analyzed to determine animal interactions through the management of data collection, selective storage of sightings, and development of algorithms to automate analyses.

14.1.9. MARINE SPATIAL PLANNING

Chapter 11 described the application of marine spatial planning (MSP) as it relates to and assists with MRE development. The purpose of MSP is to improve the governance of ocean areas for their sustainable use and to provide equity for all users, while affording environmental protection. Responses to surveys of the OES-Environmental nations described the wide range of MSP programs and applications as they apply to MRE.

Important studies and information are needed to continue improving our understanding of how MSP can support and move forward with MRE development. Needed efforts include

- creating materials for and building contacts with government policy-makers and managers to assure that those tasked with creating national and regional marine spatial plans are aware of the needs of MRE
- making data and information that support MSP processes publicly available and accessible to assure that processes are transparent, including the role that MRE can play in ocean development, ocean space allocations, and governance.

14.1.10. ADAPTIVE MANAGEMENT

Chapter 12 explored the value and application of adaptive management (AM) to MRE siting, development, and management. Using a structured incremental approach to project build-out with embedded monitoring, AM has helped move many consenting processes forward for single MRE devices and small arrays of tidal turbines.

Expanding the value that AM can bring to MRE will require

- publishing guidance on AM implementation within the consenting process, prepared and issued by the appropriate regulatory body
- producing implementation guidance for the MRE industry to clarify the circumstances under which AM is acceptable, and to include requirements for post-installation monitoring, stakeholder engagement, information sharing, and thresholds for AM intervention
- applying AM measures as mechanisms for decreasing financial risk to the industry
- assuring comfort amongst regulators that an AM approach can be fully compliant with regulatory requirements and environmental legislation.

14.1.11. RISK RETIREMENT AND DATA TRANSFERABILITY

Chapter 13 presented the concepts and initial implementation of risk retirement and data transferability as a means of facilitating and accelerating consenting for small numbers of MRE devices (one or two most likely), whereby each potential risk need not be fully investigated for every project. Rather, we recommend that MRE developers and regulators rely on what is already known from already consented and deployed projects, from related research studies, or from findings of analogous offshore industries. When larger arrays of MRE devices are planned, or when new information comes to light, these risks may need to be revisited and new decisions about the level of risk retirement could be made. The intent of the process is to provide assistance to regulators in their decision-making and to inform the MRE community of what is likely to be required for consenting small developments, as well as helping to distinguish between perceived and actual risk to the marine environment. Risk retirement will not take the place of any existing regulatory processes, nor will it completely replace the need for all data collection before and after MRE device deployment; these data are needed to verify the risk retirement findings and add to the overall knowledge base. A process for assuring that appropriate datasets and information are readily available (data transferability) is also discussed. Inherent in the risk retirement and data transferability processes is the necessary protection of the environment and inhabitants of the areas into which MRE devices will be deployed and working within all existing regulatory frameworks.

The concepts of risk retirement and data transferability are relatively new. Considerable work is needed to test whether these concepts have value in MRE development and marine environmental protection, and to see if they can succeed in simplifying these pathways. Necessary activities to further risk retirement include

- increasing outreach and engagement with regulators in many nations to further explain the process and understand their potential for applying risk retirement to consenting processes
- engaging with MRE device and project developers, researchers, consultants, and other stakeholders to gain their trust in the process and to assure they understand what regulators will require of them if risk retirement is applied
- gathering evidence of additional stressors and augmenting the existing evidence base for underwater noise and EMFs as new data become available
- translating into regulatory language the evidence base for each stressor for each participating nation, working closely with regulators.

14.2. CHARTING A PATH FORWARD FOR MRE CONSENTING

By bringing together the information about the potential interactions of marine animals, habitats, and ecosystem processes with MRE devices and systems, this report provides a snapshot of the knowledge in 2020 derived from multiple field, laboratory, and modeling studies conducted around the world. The value of this information is realized as we apply it to consenting processes, and may be informed by applying some of the strategies discussed in the latter chapters of this report: MSP, AM, and risk retirement. Collectively, we might consider this body of information as supporting responsible development of MRE through continued streamlining of consenting processes. In addition, we need to consider how these management strategies support consenting and management of MRE projects through the following lenses:

- proportionate consenting requirements
- sufficiency of evidence
- transferability of evidence
- retirement of specific issues and downgrading of others that may be retired in the future.

14.2.1. PROPORTIONATE CONSENTING REQUIREMENTS

In many parts of the world, the MRE industry has been required to collect significant baseline and post-installation monitoring data for each proposed demonstration, pilot, or commercial project. At times, the requirements for data collection appear to be out of proportion relative to the size of the project and the likely risk to marine receptors. The purpose of the strategies and planning concepts highlighted here (MSP, AM, risk retirement) is to assist in converging on proportionate data collection, analysis, and reporting for consenting. Some site-specific data collection will be required at each proposed MRE project site to assure that models and information collected far from the site are applicable. However, relying on the knowledge of stressor-receptor relationships and likely risk from already consented projects, analogous industries, and research studies can bring these efforts closer to the proportionate consenting that will move the industry forward.

14.2.2. SUFFICIENCY OF EVIDENCE

For each MRE project, it is the duty of regulators to assure that sufficient evidence that is proportionate to the risk is gathered to evaluate the risk to critical marine species and habitats, and the responsibility of stakeholders to question whether the regulatory process is fair and sufficiently protective of the marine environment while not being overly precautionary. At this early stage of MRE development, validating whether the evidence base is sufficient is not a clear and simple process. The process of MSP enables governments and all sectors to come together to identify optimal locations for MRE development, which will allow for the creation of this secure low-carbon energy source, while protecting the marine environment. AM can also play a key role in allowing feedback loops and learning from each subsequent project, granting regulatory bodies and advisors leeway to adjust requirements based on post-installation monitoring data and outcomes from the initial operation of MRE devices.

14.2.3. TRANSFERABILITY OF EVIDENCE

Inherent in determining under what conditions sufficient evidence exists for consenting purposes is the need to examine information collected at other MRE development locations, and to apply lessons learned from analogous offshore industries and targeted research projects. Evaluating and understanding what data and information are valid for application to consenting new MRE sites is challenging. This process will become more transparent as more deployments and evaluations take place worldwide. The data transferability process proposed in this report, as part of the risk retirement pathway, is intended to organize and begin the process of making routine transfer of evidence more efficient.

14.2.4. RETIRING SPECIFIC ISSUES

Some stressor-receptor interactions may be of greater importance in certain countries, based on local sensitivities or other needs. These issues are likely to be given greater attention and inquiry through research investigations or post-installation monitoring requirements. For example, in France, to prevent corrosion of MRE structures, the developers opt to use sacrificial anodes. The use of these metal-based anodes has raised concerns about the potential contamination of nearby waters and habitats, which have resulted in an extensive study of potential concentrations of the metals that might be shed into nearshore waters. The preliminary results of this study show a very limited environmental risk due to metals concentration in nearshore waters, which might result in the risk being retired for France (De Roeck, pers. comm).

As the MRE industry develops and more deployments yield monitoring data and studies, the accurate nature of specific stressor-receptor interactions will become clearer. At this early stage, efforts such as the risk retirement process suggested in this report will help determine for which of these interactions sufficient evidence exists, and where there are still significant uncertainties. By decreasing the need to study each stressor-receptor interaction at each new project site, the focus of project developer funds and scientific expertise can be on the interactions for which not enough is known to clearly judge the associated levels of risk. Understanding of some of the more challenging stressor-receptor relationships, such as collision risk for marine animals around turbines, will progress much faster with this focus. By retiring specific issues for small numbers of devices and planning to re-examine these same interactions with larger arrays, we will move toward a simpler but proportionate protective process for consenting.

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NOTES

Summary and Path Forward

Copping, A.E. 2020. Summary and Path forward. In A.E. Copping and L.G. Hemery (Eds.), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). (pp. 280-292). doi:10.2172/1633209

REPORT AND MORE INFORMATION

OES-Environmental 2020 State of the Science full report and executive summary available at:
https://tethys.pnnl.gov/publications/state-of-the-science-2020

CONTACT

Andrea Copping
Pacific Northwest National Laboratory

andrea.copping@pnnl.gov

+1 206.528.3049

Go to *https://tethys.pnnl.gov* for a comprehensive collection of papers, reports, archived presentations, and other media about environmental effects of marine renewable energy development.