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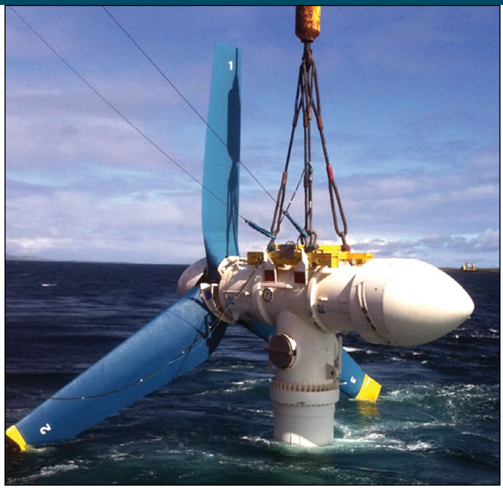

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Risk Retirement and Data Transferability for Marine Renewable Energy

WHAT DO WE MEAN BY "RISK RETIREMENT"?

This chapter discusses a process for facilitating consenting for single marine renewable energy (MRE) device deployments, demonstration projects and small arrays, whereby each potential risk need not be fully investigated for every project. Rather we recommend that MRE developers and regulators rely on what is known from already consented projects, from related research studies, or from findings from analogous offshore industries. When larger arrays of MRE devices are planned, or when new information comes to light, these risks can be revisited and new decisions about the level of risk downgrading or retirement can 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 single device deployments, demonstration projects and small arrays, as well as to help 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 appropriate data collection before and after MRE device deployment; baseline data that are not available for a particular site may be needed to enable an assessment of site-specific environmental sensitivities, verify risk retirement findings and add to the overall knowledge base.

Large-scale marine renewable energy (MRE) developments continue to progress slowly, in part because of complicated consenting/permitting (hereafter consenting) processes that invoke the precautionary principle within environmental legislative frameworks. This can lead to broad, poorly scoped environmental assessments, lengthy and expensive environmental data collection requirements, and extended consenting timelines. Much of this delay is associated with uncertainty about the potential effects of MRE on marine animals and habitats (Copping 2018).

This uncertainty may lead regulators and stakeholders to believe that significant risks exist, thereby resulting in a more precautionary approach to consent determination and other decision processes, and possibly lengthy and disproportionate baseline data collection and ongoing monitoring requirements. These, in turn, slow consenting processes and increase costs to the emerging MRE industry and places additional pressure on regulators and their advisors. In addition to being frequently associated with scientific uncertainty, these perceptions of risk may result from lack of familiarity with and access to existing scientific information relevant to the interactions of MRE devices with marine animals or habitats. This chapter documents a path for streamlining consenting processes by examining the potential for risk retirement of specific stressor-receptor interactions, that can help to distinguish between perceived and actual risk to the marine environment. This process has been developed in cooperation with the nations engaged in pursuing environmental effects investigations under the International Energy Agency (IEA) Ocean Energy Systems (OES) task OES-Environmental (see Chapter 1, Introduction).

13.1 DEFINITION OF RISK RETIREMENT

The term "risk retirement" has been used by technology-focused development programs such as geotechnical risk management to delineate circumstances in which key stressor-receptor interactions are sufficiently understood to alleviate the need to carry out detailed investigations for each proposed project (NAS 2018). The term has also been used by the MRE community to describe a means of simplifying the consenting processes by focusing on key issues of concern (Copping et al. 2016; Robertson et al. 2018). However, there is no specific definition and little understanding of how risk might progress to a less active state of investigation or retirement. OES-Environmental aims to examine and define the possibilities of how risk retirement might be manifested and provide a pathway forward that will help streamline consenting processes.

Based on interactions with the MRE industry, regulators, researchers, and other stakeholders, and the scientific evidence set out in this report, it is clear that certain interactions with aspects of operational MRE systems pose little to no risk to the marine environment. For example, the risk of chemical leaching from system components, including oil, is widely considered to be negligible because few such products are used on MRE devices (Copping et al. 2016). Similarly, other stressor-receptor interactions can be informed by established industries, such as aggregation of fish and invertebrates around floats and anchor lines, which has no demonstrable mechanism for harming the marine environment (Copping et al. 2016; Copping 2018). These risks might be considered to be retired, or no longer in need of active investigation for each individual MRE project, but the requirement will always remain at the discretion of the regulatory body. Any indirect effects of some of these interactions observed in the future will need further investigation once large commercial arrays are in operation. With few operational MRE arrays in the water at this time, it is appropriate to focus processes for risk retirement on what is known about single devices, demonstration projects and small arrays.

The risk retirement approach described here follows the concept of stressors and receptors (Boehlert and Gill 2010). The stressor-receptor interactions that are collectively recognized as key issues by regulators, developers, stakeholders and researchers are associated with the following:

- potential collision of marine animals with tidal turbine blades
- effects of underwater noise from MRE operation on marine animal behavior and health
- potential effects of electromagnetic fields (EMFs) from cables and energized devices on sensitive marine species
- changes in benthic and pelagic habitats from MRE anchors, foundations, and mooring lines
- displacement of or barrier effect on migratory animal populations from arrays of MRE devices
- changes in circulation and sediment transport as a result of operational MRE devices, as well as the effects of energy removal from the system
- potential entanglement of marine animals in mooring lines for many wave devices and some tidal turbines.

The appropriate level of risk associated with each of these stressor-receptor interactions can be resolved with the application of rigorous research and monitoring results, as well as lessons learned from other industries (see previous chapters). While interactions with the MRE community of regulators, researchers, developers, and other stakeholders suggest that the effects of underwater noise and EMFs may be good candidates for retiring risks for small numbers of MRE devices (see Section 13.3), other stressor-receptor interactions, like collision risk, may require further research and monitoring, while displacement or barrier effects will not be resolved until larger arrays are deployed and studied. The risk retirement steps described below and depicted in Figure 13.1 are aimed at developing criteria to minimize, downgrade, or retire the risks that are not likely to cause harm to the marine environment.

13.2 THE RISK RETIREMENT PATHWAY

A risk retirement process has been developed with the intent of lowering barriers to consenting and licensing MRE projects for widespread and accelerated development. This approach does not advocate taking shortcuts or lowering standards for environmental protection, but rather is focused on achieving a balance between environmental precaution and the proportional risk created by MRE systems, as well as helping to distinguish between perceived and actual risk to the marine environment. The process begins with a systematic examination and cataloging of datasets from wave and tidal projects that have been consented, assuring that the datasets are accessible and understandable to regulators. If this process is successful, the burden of evidence for projects for which risks have been retired ought to be reduced, and the particular stressor of interest ought to play a less critical role in the overall consenting process. Legislation and regulation in each country will dictate the precise language that regulators must use to conclude the importance of a stressor-receptor interaction, but the overall process of downgrading and retiring risk should be useful in most circumstances.

Based on feedback from surveys of regulators from several countries participating in the OES-Environmental task and direct interactions with United States (U.S.) regulators, a risk retirement pathway (Figure 13.1) was developed to determine whether potential risks from an MRE project can be downgraded or retired. 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 the consenting of single devices, demonstration projects and small arrays. Assuring that datasets and knowledge from consented MRE projects are readily available and cataloged is a key aspect of the risk retirement pathway. This accessibility of datasets and knowledge allows a proposed project to be compared to, and utilize evidence from, existing consented projects so that associated lessons learned and knowledge from the latter can be shared. This portion of the process involves the concepts of data and knowledge transferability and data collection consistency (Freeman et al. 2018), explained in more detail in Section 13.4. Adaptive management also plays an important role by allowing regulators and project developers to systematically view monitoring and analysis outputs, and adjust the level of mitigation and monitoring focus accordingly (Wiesebron et al. 2016).

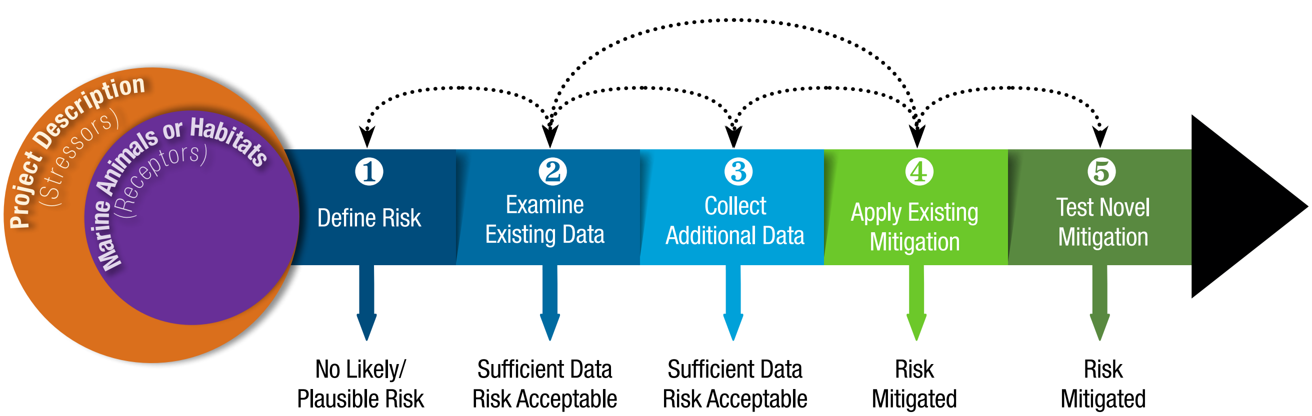

Figure 13.1. Risk retirement pathway. The dotted arrow lines represent the feedback loops between each stage of the pathway. The downward arrows at the bottom of each stage indicate the off ramps where a risk might be considered retired or downgraded. (Graphic by Robyn Ricks)

The risk retirement pathway was developed to provide a method for advancing from determining the level of risk from any stressor-receptor interaction toward a set of solutions based on the best use of available evidence and a proportionate approach to determining any additional evidence needs. The pathway aims to facilitate more streamlined consenting (Figure 13.1). The pathway also implies that a risk can be revisited by following the same process, if additional information suggests further review is needed.

As the risk retirement pathway indicates, the specific project details must first be defined for the project of interest, starting with a description of the project (site characteristics and development type and size) and the animals or habitats that may be affected (Figure 13.1, orange and purple rings). It is essential to include information about the size of the proposed development because single devices are less likely to have significant effects than arrays (see previous chapters). Next in the pathway is a series of stage gates or phases, during which the project is compared to existing data, knowledge, and lessons learned from other consented projects. Each stage incorporates an "off ramp" (implied by the downward-facing arrows in Figure 13.1) to allow the risk to be considered retired if there is sufficient information to do so. As noted, the concept of risk retirement is associated with a decreased need to examine the stressor-receptor interaction at each new project site. If at any stage there is not sufficient information to determine that the risk might be retired (via an off ramp), the risk moves to the next stage to the right. More detail about the stages can be found on the *Tethys* website[1] and in Copping et al. (2020a, 2020b).

In moving from one stage to the next on the risk retirement pathway, available knowledge needs to be examined to determine whether a project can progress to the next stage and to provide feedback among the stages. This application of data to inform the process has been termed "data transferability" (see Section 13.4) and comes into play mainly during stages 1 and 2. In addition to applying existing data (data transfer) to inform progress from stage to stage, the generation of new data from monitoring, research studies, experiments, or development of new effective mitigation measures may require datasets to inform the process (signified by the dotted arrows on the top of the diagram; Figure 13.1).

1. *https://tethys.pnnl.gov/risk-retirement*

13.3 APPLICATION OF THE RISK RETIREMENT PATHWAY TO MRE INTERACTIONS

Based on the understanding of interactions between MRE systems and the marine environment, OES-Environmental identified two stressors (underwater noise and EMFs) as candidates for risk retirement related to small numbers of devices. The evidence base for considering risk retirement for these two stressors is presented here. Additional detail and relevant studies are found in Chapters 4 (Risk to Marine Animals from Underwater Noise Generated by Marine Renewable Energy Devices) and 5 (Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices) as well as on the *Tethys* website[2]. During 2019, the evidence base was presented at three workshops to a cross section of experts and practitioners in the MRE community (Box 13.1). Each workshop used hypothetical, but

BOX 13.1.

RISK RETIREMENT WORKSHOPS

An international workshop was held in concert with the European Wave and Tidal Energy Conference 2019 (EWTEC) in Napoli, Italy (September 1–6, 2019), attended by 34 experts from 11 nations. The workshop evaluated the risk retirement pathway using hypothetical examples for underwater noise and electromagnetic fields, mainly focusing on stages 2 (Examine Existing Data) and 3 (Collect Additional Data).

A second workshop, targeted toward a largely American audience, was held at the Ocean Renewable Energy Conference 2019 (OREC) in Portland, Oregon, United States (September 10–12, 2019). The risk retirement pathway was evaluated using two hypothetical examples for underwater noise. Focusing once again on stages 2 (Examine Existing Data) and 3 (Collect Additional Data) of the risk retirement pathway, the workshop experts examined the evidence to determine whether participants felt the risk could be retired for underwater noise for wave and tidal devices.

A third workshop targeted toward an Australian audience was held in Sydney, Australia (December 4, 2019). In addition to presentations to familiarize participants with the current state of the science on environmental effects of marine renewable energy, the risk retirement pathway and data transferability processes related to underwater noise and electromagnetic fields were presented. Similar to the other workshops, two hypothetical examples were used to evaluate risk retirement.

2. *https://tethys.pnnl.gov/events/retiring-risks-mre-environmental-interactions-support-consentingpermitting*

realistic, MRE developments to apply the evidence base and evaluate risk retirement. The consensus among participants was to accept the evidence toward risk retirement, but consider some additional caveats and data collection requirements.

13.3.1
EFFECTS OF UNDERWATER NOISE ON MARINE ANIMALS

As described in Chapter 4 (Risk to Marine Animals from Underwater Noise Generated by Marine Renewable Energy Devices), monitoring around single devices, as well as field research, indicate that underwater noise emitted from operational MRE devices can be detected by many marine animals but is unlikely to significantly alter their behavior or cause them physical harm (e.g., Baring-Gould et al. 2016). The sound levels of devices, either wave energy devices (WECs) or tidal turbines, appear to fall below existing U.S. regulatory thresholds for marine mammals and fish (NMFS 2018; Tetra Tech 2013). Operational noise from MRE devices also falls below the frequency thresholds at which most marine mammals hear (Haikonen et al. 2013) and has been shown to be of lower amplitude than other industrial activities such as commercial shipping (Lossent et al. 2017).

The evidence base for underwater noise from turbines and WECs includes studies completed by Cruz et al. (2015), Farcas et al. (2016), Hafla et al. (2018), Haikonen et al. (2013), Lepper and Robinson (2016), Lossent et al. (2018), Schmitt et al. (2015, 2018), and Tougaard (2015). To investigate the effects of underwater noise during the three aforementioned workshops (Box 13.2), a selection of hypothetical, but realistic, MRE examples was used. One of the examples included a bottom-mounted axial-flow tidal turbine (Figure 13.2) for which the sound generated by the rotating blades and the power take-off fell in the 118–145 dB re 1 µPa at 1 m range, over frequencies of 40 Hz to 8 kHz (see definitions in Chapter 4, Risk to Marine Animals from Underwater Noise Generated by Marine Renewable Energy Devices).

BOX 13.2.

FEEDBACK FROM RISK RETIREMENT WORKSHOPS FOR UNDERWATER NOISE

At the EWTEC workshop, participants found the risk retirement pathway intuitive and easy to navigate. They agreed that, in addition to the existing sound at a site, the risk associated with underwater noise from marine renewable energy (MRE) could be retired for single devices and small arrays, with the caveat that a library of standardized noise measurements produced by MRE is needed. The recommendation is to measure *in situ* the underwater noise from each wave or tidal device for which deployment/development consent is sought, using the International Electrotechnical Commission (IEC) Technical Committee (TC) 114 Level B recommendations (IEC 2019). In the United States (U.S.) context, provided that the underwater noise from a device falls below the U.S. thresholds (NMFS 2018; Tetra Tech 2013), the risk could be retired. However, it was noted that different countries have different requirements, so some additional work with regulators is needed to assure that the pathway becomes acceptable under the particular nation's legislation. Gaps in information that would allow a similar analysis for large MRE arrays were noted, including the need to verify noise propagation models because they might apply to underwater noise from large arrays in the high-energy waters in which MRE development is targeted to occur.

At the OREC workshop, participants felt that risks from underwater noise were close to retirement for single devices. In addition to supporting the concept of measuring noise outputs from operational devices and comparing those outputs to U.S. regulatory thresholds, the participants were interested in understanding how marine animals might be using the habitats immediately surrounding the device and how they might behave in response to the noise produced by the device. Acquiring further information about underwater noise from arrays was thought to be important, including the spacing of devices to minimize overall noise inputs to an area and the role that test centers could play in measuring underwater noise under operational conditions.

At the Sydney workshop, participants thought the concept of risk retirement fit well in an Australian regulatory context and that both the risk retirement and data transferability processes added value by providing a systemic analysis that regulators can put into practice. It was noted that additional precautionary steps may be required in specific locations where sensitive species are present. Based on the evidence presented and the U.S. thresholds available for noise effects on marine mammals and fish, participants agreed that underwater noise could be retired for single devices or small arrays. Participants also noted that cumulative effects may become an issue in the future because many sources of anthropogenic noise are already occurring in the marine environment.

13.3.2.
EFFECTS OF EMFS ON MARINE ANIMALS

As described in Chapter 5 (Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices), field research, laboratory studies, and modeling simulations indicate that EMFs from cables are likely a small risk to animals, and one that is easily mitigated by burying the cable if needed (Copping et al. 2016). Given the more than 100-year history of deploying electrical and telecommunications cables in the ocean, EMF signatures are not new to the marine environment. Understanding the effects of EMFs on marine animals can be informed by previous experience with subsea cables used for power and telecommunications, bridges, tunnels, and offshore wind farms that have been deployed and emit measurable EMF signatures in the ocean (Electric Power Research Institute 2013; Meißner et al. 2006).

The evidence base for EMFs from submarine cables includes studies by Hutchison et al. (2018), Kavet et al. (2016), Love et al. (2017), Sherwood et al. (2016), Thomsen et al. (2015), Westerberg and Lagenfelt (2008), Woodruff et al. (2012), and Wyman et al. (2018). To investigate EMFs during two workshops (Box 13.3), a selection of hypothetical, but realistic, examples was used. One of the examples included a floating oscillating water column WEC placed on the sea surface with an energized vertical cable in the water column connected to an offshore substation and an export cable on the seafloor running from the offshore substation to an onshore substation (Figure 13.3).

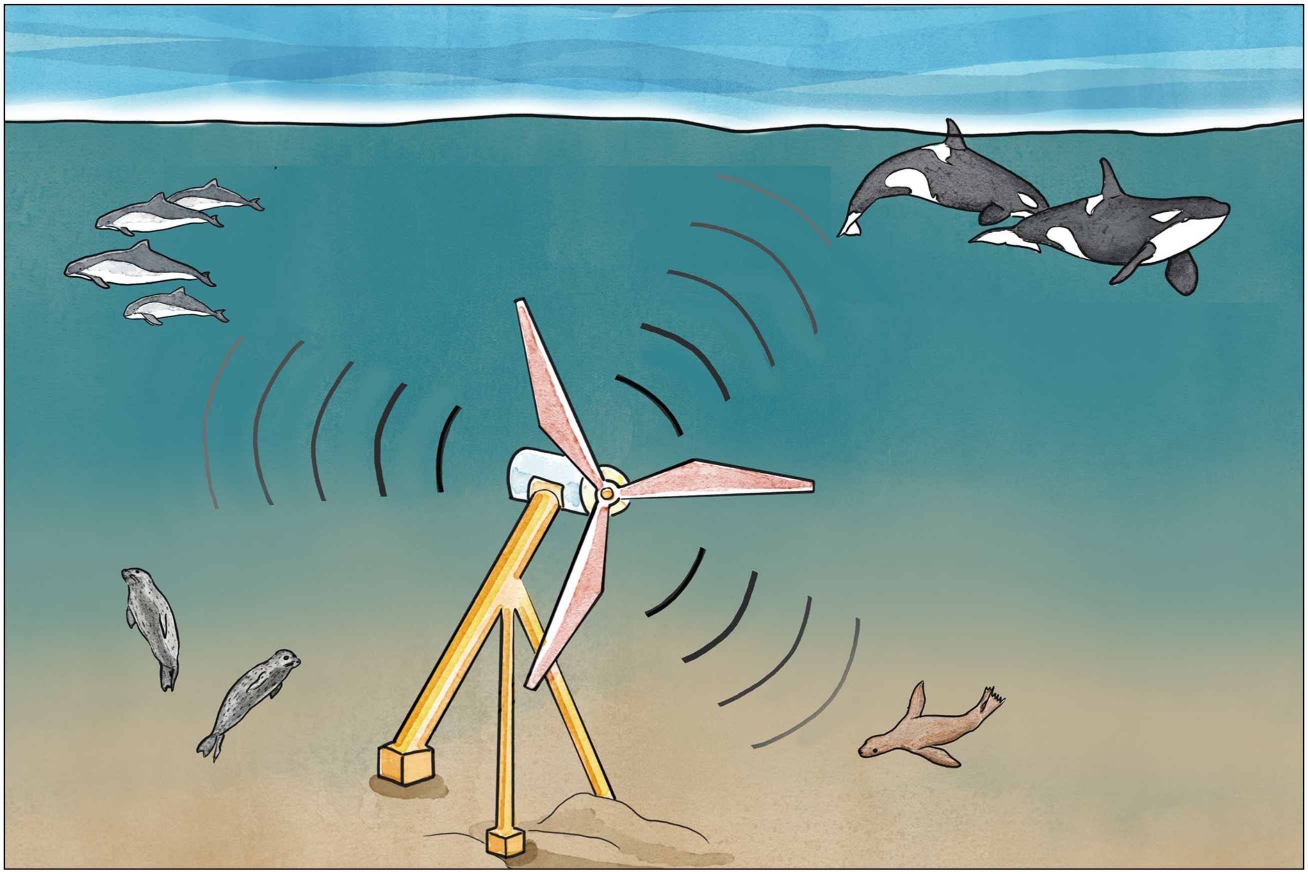

Figure 13.2. Hypothetical example of a tidal turbine emitting noise (represented by the grey semi-circles) in an area used by harbor porpoises, harbor seals, sea lions, and orca whales. Graphics similar to this figure were used at the expert workshops to denote the presence of certain animal species, or receptors, in the vicinity of the turbine, and to help visualize potential stressor-receptor interactions. The animals, turbine, and water depth are not drawn to scale. (Illustration by Rose Perry)

BOX 13.3

FEEDBACK FROM RISK RETIREMENT WORKSHOPS FOR ELECTROMAGNETIC FIELDS

At the EWTEC workshop, participants surmised that electromagnetic fields (EMFs) are not a likely risk, because the level of power carried in marine renewable energy (MRE) cables is very small compared to that from, for instance, offshore wind farms. However, they did agree that some basic information (e.g., baseline data about species and habitats, presence of other cables in the area) would be required to retire the risk for single devices. Participants also highlighted how relatively little is known about EMF-sensitive species and how they might be affected. Some of the strategic gaps identified were the need for field measurements of EMFs to improve and validate models, increased understanding of how EMF emissions vary with power variability, and help in identifying potential risks associated with offshore substations and vertical and draped cables. Participants also expressed concerns regarding the difficulties in establishing EMF thresholds and the cumulative effects of EMFs in the benthic and pelagic environments.

At the Sydney workshop, participants thought that without regulatory thresholds for EMFs it could be challenging to retire this risk, especially because regulators are likely to be risk-averse without guidance. They felt it would be important for EMF experts to put forth some plausible thresholds and work with the MRE industry to help regulators understand that risk will be minimal. Experiences related to consenting an upcoming MRE deployment in Australia demonstrated that burying the export power cable satisfied regulatory needs. Overall, participants agreed that the risk could be retired for single devices, demonstration projects and small arrays, or small arrays, but felt there were effects from EMFs that may still require measurements to be taken.

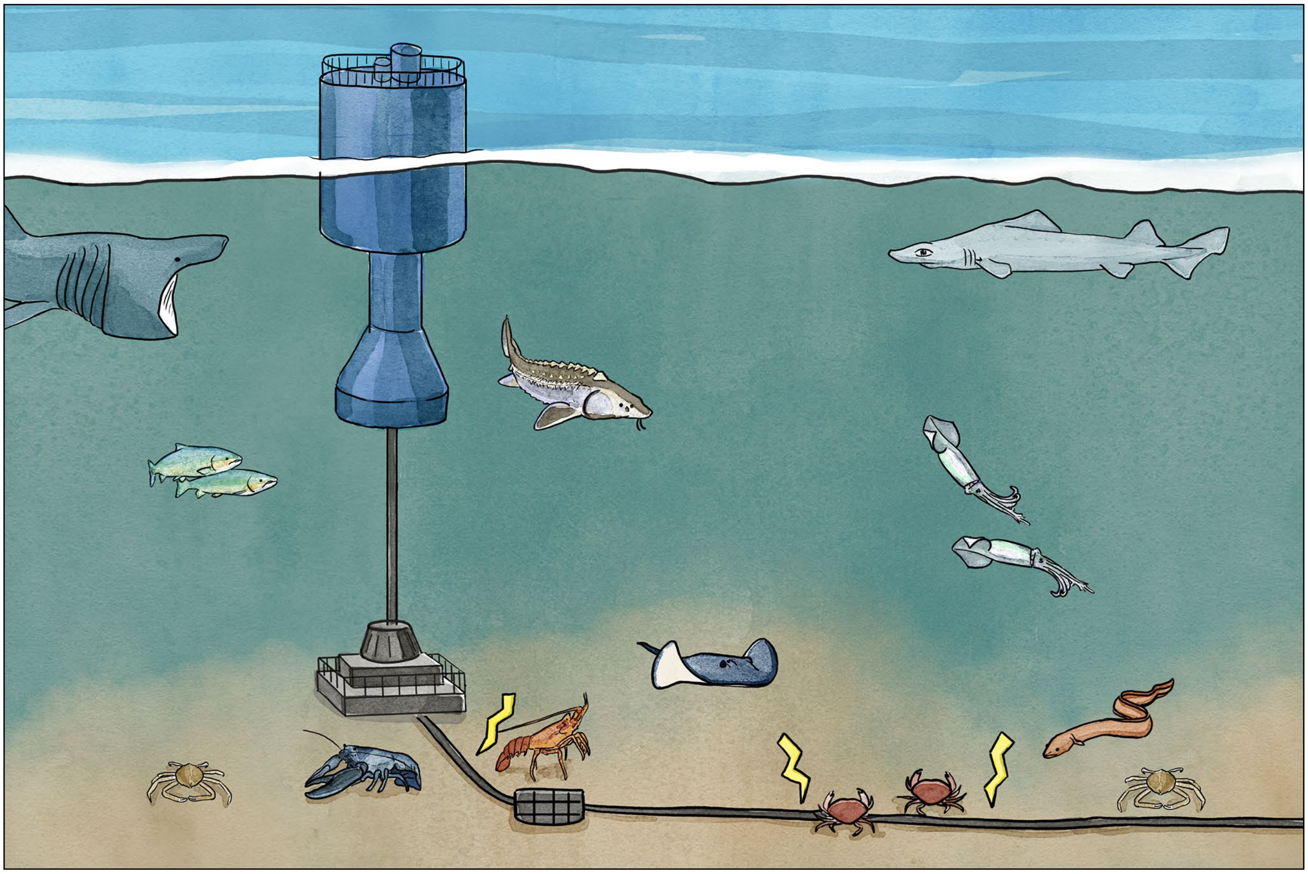

Figure 13.3. Hypothetical example of a wave energy converter (WEC) with cables emitting electromagnetic fields (represented by the lightning bolts along the cable) in an environment used by sharks, skates, bony fishes, crustaceans, and other invertebrates. Graphics similar to this figure were used at the expert workshops to denote the presence of certain animal species, or receptors, in the vicinity of the WEC, and to help visualize potential stressor-receptor interactions. The animals, device, and water depth are not drawn to scale. (Illustration by Rose Perry)

13.4. DATA TRANSFERABILITY PROCESS

In an MRE context, the process of data transferability refers to applying existing learning, analyses, and monitoring datasets from one country to another, among projects, and across jurisdictional boundaries. This process could help satisfy regulatory requirements for MRE developments and subsequently reduce costs and burden to the industry over time, while also protecting the marine environment. To efficiently transfer these datasets, it is advisable for information and data to be comparably collected, analyzed, and interpreted among projects. Currently, information and data are collected around early-stage MRE devices that use many different parameters and methods. If good management practices were applied to standardize methods of collection for baseline and post-installation monitoring around early-stage devices, the results would be more readily comparable, could lead to a decrease in scientific uncertainty, and would support a common understanding of the risk of stressor-receptor interactions. This, in turn, would facilitate more efficient and shorter consenting processes, which would decrease financial risk for MRE project developments, reduce burden and requirement for additional resources for regulators, and subsequently move deployment of wave and tidal devices forward more rapidly. Overall, the purpose of examining the potential for achieving data transferability and data collection consistency is to shorten regulatory timelines and provide greater standardization in baseline and post-installation data requested to support the consenting of MRE projects across multiple jurisdictions.

As a first step toward developing a process for transferring data, the U.S. regulatory community from state and federal jurisdictions responsible for MRE consenting was surveyed to determine the level of understanding of MRE technologies, priorities for consenting risk, and willingness to transfer data (Copping et al. 2018). The regulator engagement outcomes helped tailor materials and methods for future engagement efforts related to the proposed approach to data transferability. U.S. regulators were further engaged through a series of online workshops. The regulators were presented with MRE data from previously consented projects or research studies to provide them with background information and gauge their comfort in using data and information of this nature in their jurisdictions. Based on the feedback received, OES-Environmental developed a data transferability process. The international research and development community was then brought together at a workshop in June 2018 in conjunction with the International Conference on Ocean Energy to gather additional feedback about data transferability, to review and modify proposed best management practices, and to discuss ways to implement the process. Additional details and materials about data transferability outreach and engagement can be found on the *Tethys* website[3].

The data transferability process (described in more detail by Copping et al. 2018, 2020c) consists of four components (Figure 13.4): (1) data transferability framework, (2) data collection consistency table, (3) monitoring datasets discoverability matrix, and (4) best management practices (BMPs). Additional details about applying the process can be found on the *Tethys* website[4]. This process is expected to be useful for regulators, developers, and other stakeholders to help with discovery and comparison of existing datasets that have potential stressor-receptor interactions that may be present in planned MRE projects, and to help provide insight into how the outcome of these interactions might be assessed.

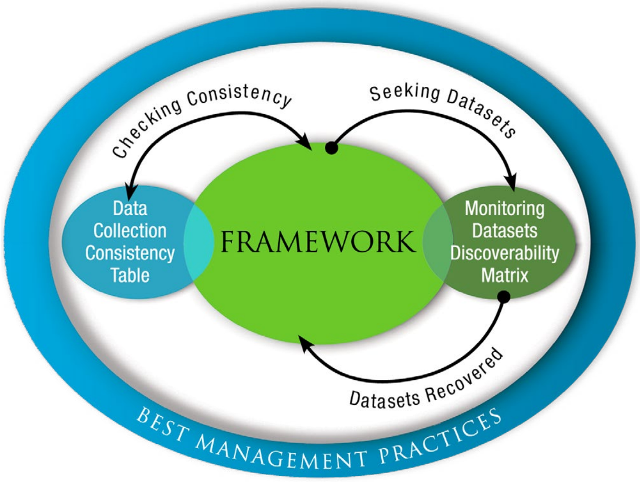

Figure 13.4. The data transferability process consists of a data transferability framework, data collection consistency table, monitoring datasets discoverability matrix, and best management practices. (Graphic by Robyn Ricks)

3. *https://tethys.pnnl.gov/data-transferability#Outreach%20&%20Engagement*

4. *https://tethys.pnnl.gov/data-transferability*

13.4.1.
DATA TRANSFERABILITY FRAMEWORK

The data transferability framework (hereafter framework) guides the overall process of data transfer by bringing together datasets (e.g., information, raw data, reports, results) from already consented projects in an organized fashion to facilitate access and assist in the assessment of knowledge for use in consenting future projects. This process may be expedited if datasets are collected in a consistent way using preferred measurement methods or processes.

The framework can be used by regulators, developers, and other stakeholders to develop a common understanding of data types and parameters to determine and address potential effects and set limits and considerations for how the BMPs can be applied to assist with effective and efficient siting, consenting, and post-installation monitoring and mitigation.

The framework uses four variables (stressor, receptor, site condition, and MRE technology type) to define a stressor-receptor interaction. Classifying each project using these four variables is the first step in determining the ability to transfer knowledge from already consented projects to future projects. While the framework is intended to help assess the transferability of information and learning from one consented project to a new project, the tenets are also applicable to knowledge gleaned from research studies and other investigations. Once datasets and other knowledge have been identified as being suitable for transferability, they can be applied to the assessment of new MRE projects.

13.4.2.
DATA COLLECTION CONSISTENCY

MRE is an international industry, whose consenting processes and research norms differ from country to country, region to region, and among research and commercial data collection efforts. It would be difficult to enforce the use of specific protocols or instruments to collect pre- or post-installation monitoring data for projects in all jurisdictions. However, encouraging the use of consistent methods and units that have been shown to be effective for the collection of monitoring data can increase confidence in the transfer of data or learning from already consented projects to future projects. Assuring that the information and data from an already consented project are compatible with the needs of future projects, and that knowledge from one or more projects can be aggregated, requires an evaluation of the degree to which collection methods and units are consistent and data are applicable to similar receiving environments.

For six of the stressors, a set of processes, reporting units, and generalized analysis or reporting methods is proposed in the data collection consistency table (Table 13.1). The preferred process (measurement methods) or measurement tools are reported for each stressor, along with preferred reporting units and the most common methods of analysis or interpretation and use of the data. If applied worldwide, the use of this table may enable researchers and developers to effectively collect data in a consistent manner and standardize monitoring methods, as well as allow regulators to evaluate existing data consistently. Over time, this would result in the increased consistency and reliability of monitoring data, as well as the streamlining of data transfer.

13.4.3.
MONITORING DATASETS DISCOVERABILITY MATRIX

The monitoring datasets discoverability matrix (hereafter matrix) classifies monitoring datasets from already consented projects by the six stressors previously discussed. The matrix is linked to key features of each dataset, including location, metadata on that site, monitoring or siting reports, links to downloadable data when available, and a contact for discussing or accessing the data. The matrix, developed as an interactive tool on the *Tethys* website[5],will allow regulators, developers, and others in the MRE community to discover datasets by key characteristics (such as stressor, receptor, site condition, MRE technology, etc.). After datasets are identified, there is an opportunity to evaluate the consistency of information and to determine whether the data can be transferred to inform applications and decisions for new projects.

13.4.4.
BEST MANAGEMENT PRACTICES

BMPs are defined as practices or procedures that can help to guide implementation of broad guidelines. The BMPs for data transferability underscore the process of evaluating datasets for transfer among the projects and consistency in data collection methods, as well as the useful support of numerical models and application of data collected for other purposes in the project area (for more detail see Copping et al. 2018, 2020c).

5. *https://tethys.pnnl.gov/monitoring-datasets-discoverability-matrix*

The process of implementing the BMPs for data transferability and collection consistency will require the confidence and good will of all parties that play a role in consenting MRE devices. Achieving an appropriate level of acceptance and use will require the following:

- Regulators and other stakeholders must be willing to accept the premise of data transferability so that they apply the principles of data transferability and collection consistency to evaluate and comment on consenting applications.
- Device and project developers must recognize the value of data transferability and commit to collecting and providing data that are consistent with the collection guidelines and that will best fit the framework recommendations from the data collection consistency table.
- Researchers and consultancies should inform themselves of the data consistency needs and potential use of data collected around MRE devices to assure that research data are usable for transfer.

Table 13.1. Data collection consistency table.

Stressor	Process or measurement tool	Reporting unit	Analysis or interpretation
Collision risk	Sensors include: • active acoustic only • active acoustic + video • video only • observations from vessel or shore	Number of visible targets in field of view, number of collisions.	Number of collisions and/or close interactions of animals with turbines, and probability of encounters, used to validate collision risk models. Avoidance or evasion Density of animals that may raise risk (based on subsea observations) vs. predicted densities from models or surface counts to refine collision risk models.
Underwater noise	Fixed or drifting hydrophones	Sound spectrum (amplitude as function of frequency) with units: Amplitude: dB re 1μPa at 1 m Frequency: frequencies within marine animal hearing range	Sound outputs from MRE devices compared against regulatory action levels. Generally reported as broadband noise unless guidance exists for specific frequency ranges. Development of noise propagation models for array projects from monitoring around single devices
Electromagnetic fields	Source: • cable - shielded or unshielded • other	AC or DC Voltage Amplitude in tesla units (μT or mT)	Measured EMF levels used to validate existing EMF models around cables and other energized sources.
Changes in habitats	Underwater mapping with: • sonar • video Habitat or species distribution characterized from: • mapping • existing maps • grabs and other benthic sampling gear	Area of habitat or species distribution altered, specific for each habitat type or species.	Compare potential changes in habitat and/or species distributions to maps of rare and important habitats or species to ensure that these vulnerable species and habitats are not likely to be harmed by the location of the proposed project.
Displacement / barrier effect	Population estimates on or near a project site by: • human observers • passive or active acoustic monitoring • video	Population estimates for species under special protection. Importance of high energy areas for key activities or transit.	Validation of population models, estimates of jeopardy, loss of species for vulnerable populations (locally or globally).
Changes in oceanographic systems	Numerical modeling, with field data validation for currents, turbulence, wave height, wave period, etc.	No preferred units. Indication of datasets used for validation, if any.	Data collected around arrays should be used to validate models.

13.5. APPLYING DATA TRANSFERABILITY TO SUPPORT CONSENTING

Applying the data transferability process will help address the concept of transferring knowledge and information among MRE projects, as well as collecting data consistently.

13.5.1. APPLYING THE PROCESS

The data transferability process was developed to provide a background against which discussions with regulators and other stakeholders can proceed as the key principles and limits of transferability are better understood. The data transferability process will facilitate initial consenting discussions between developers and regulators to guide data collection and monitoring efforts needed for an MRE project and determine operational monitoring needs.

While data transfer often occurs during the consenting process, these instances are rarely documented. To move the data transferability process forward, consenting licenses for which data transfer was used should be highlighted and shared with the MRE community. Through the successful development and implementation of the data transferability process, OES-Environmental will continue its efforts of outreach and engagement with relevant stakeholders to further the knowledge and understanding of the potential environmental effects of MRE devices, thereby accelerating the siting and consenting process for MRE developments.

13.5.2. DATA TRANSFERABILITY CASE STUDIES

A selection of examples from the MRE industry help describe some early successes in the transfer of data and information. We expect that many more examples will become available in the next few years of MRE development.

SME Plat-O #1 *(underwater noise stressor)*

Sustainable Marine Energy (SME) installed their PLAT-O #1 tidal energy device in Yarmouth, England, in preparation for later deployment at EMEC's Fall of Warness test site (Orkney, Scotland). Acoustic monitoring was conducted during anchor installation to measure the sound profile of the operation, specifically to note potential effects on cetaceans, seals, and basking sharks. Using a hydrophone at a depth of approximately 5 m, the sound of seabed drilling was not audible over the vessel plant noise (Aquatera 2015). The outcome of this monitoring was used to inform the development of SME's project environmental management plan for their proposed deployment at EMEC's Fall of Warness test site and, because of the results, SME was not required to implement a mitigation zone, use Marine Mammal Observers, or undertake acoustic monitoring during installation at EMEC (Marine Scotland 2015). This resulted in significant cost savings, streamlined operational planning, and reduced the number of required offshore personnel for the EMEC deployment.

Voith Hydro HyTide and Brims Tidal Array *(changes in habitat stressor)*

Pre- and post-installation underwater video data were collected at the Voith Hydro HyTide project at EMEC in 2011 to determine baseline conditions and the effect of operation on the immediate and surrounding benthic habitat (Aquatera 2011). A report about this high-level assessment was provided to the regulator and advisors, who determined that such drilling activities would have a limited footprint and therefore limited effect on the benthic habitat. These data were then transferred from the Voith Hydro project to inform the environmental impact assessment for the OpenHydro 200 MW Brims Tidal Array near Orkney, Scotland (Aquatera 2011; Brims Tidal Array 2016). Understanding of the extent (footprint) of the direct effects of drilling on benthic habitats allowed a proportionate approach to be adopted during the environmental impact assessment process, enabling developers to focus monitoring and mitigation on topics of greater scientific uncertainty.

Sabella D03 and D10 *(collision risk stressor)*

The Sabella D03 turbine was deployed in 2008 in the Odet estuary in Brittany, France. Video monitoring showed slow-moving turbine speeds that appeared to be "innocuous" to schools of fish (ETIP Ocean 2017; see the video here[6]). Lessons learned from the monitoring of the D03 turbine were transferred to the design and monitoring needs of the D10 model and are proposed to be continued in the scaling up of other Sabella devices (Paboeuf et al. 2016). The low impact and continued low speeds of rotation in the D10 model are considered to also be of minimal effect on fish. The D10 model was deployed in 2015 in Passage du Fromveur, near Ouessant, France, for a demonstration period of one year, and delivered more than 10 MWh of electricity to the grid (Sabella 2020).

***Voith Hydro HyTide and EMEC** (marine mammal receptor)*

Voith Hydro installed a 23 m monopile foundation for their HyTide tidal energy device at EMEC's Fall of Warness site in 2011, using a large offshore construction vessel with a dynamic positioning system. Marine Mammal Observers were assigned to monitor within a 1 km radius of the main installation vessel prior to and during monopile drilling activities, and to count hauled-out seals at Seal Skerry throughout the activities. Acoustic monitoring was carried out using drifting hydrophone transects to characterize the ambient noise at the project site and noise generated during monopile installation. Average counts of hauled-out seals on Seal Skerry were slightly lower during and following installation operations, but this correlation was considered likely to be due to the natural diurnal haulout patterns of seals (Aquatera 2011). No evidence of disturbance by the monopile installation operations was observed, and noise levels were found to be unlikely to cause any auditory impairment to harbor seals (Aquatera 2011). Based on these findings, a recommendation was made to EMEC and the regulator that no mitigation or observation zones be established at the test site in the future by individual vessel operators, because there was no observed effect on marine mammals (Aquatera 2011). Data from this project were also used to update EMEC guidance on mitigation of marine mammal disturbance and injury at EMEC test sites (EMEC 2019). The ability to transfer data resulted in significant savings in terms of time and cost for EMEC, as well as for future developers at EMEC test sites.

13.6. CONCLUSION

The concepts of risk retirement and data transferability have been developed by OES-Environmental to inform discussions between developers and regulators in order to reach a common understanding of evidence needs for consenting new MRE projects. This includes assuring that any identified site-specific data needs are proportionate and account for existing relevant knowledge and data, such as assuring that the assumptions made during these processes are correct, and including marine animals and habitats that are particular to the specific location.

The groups that have convened to examine the processes and evidence bases for risk retirement of underwater noise and EMFs were generally in agreement that these stressors could be retired for small MRE projects, but that additional information needs to be added to the evidence base. The data transferability process, particularly the accessibility of datasets from consenting projects, has also received strong support from these groups. The monitoring dataset discoverability matrix will become increasingly useful as more MRE developments are consented in the future and additional datasets become available.

While information and products developed under OES-Environmental are produced in English, there are many countries engaged in MRE development where regulators work primarily in other languages. Processes such as risk retirement and other management strategy tools need to be translated into additional languages to optimize their usefulness.

Additional information about the processes, reports and/or recordings from the various workshops and webinars, and outcomes of risk retirement and data transferability can be found on the *Tethys* risk retirement and data transferability webpages.

6. *https://www.youtube.com/watch?v=MNsKpddt3ew*

13.7. REFERENCES

Aquatera. 2011. Farr Point Wave Farm Development: Request for Scoping Opinion. Report by Aquatera for Pelamis Wave Power, Orkney, Scotland. *https://tethys.pnnl.gov/publications/farr-point-wave-farm-development-request-scoping-opinion*

Aquatera. 2015. SME Project Environmental Monitoring Plan. Orkney, Scotland. Available by request.

Baring-Gould, E., Christol, C., LiVecchi, A., Kramer, S., and West, A. 2016. A Review of the Environmental Impacts for Marine and Hydrokinetic Projects to Inform Regulatory Permitting: Summary Findings from the 2015 Workshop on Marine and Hydrokinetic Technologies, Washington, D.C. (Report No. NREL/TP-5000-66688). Report by National Renewable Energy Laboratory for U.S. Department of Energy, Golden, Colorado. *https://tethys.pnnl.gov/publications/review-environmental-impacts-marine-hydrokinetic-projects-inform-regulatory-permitting*

Boehlert, G. W., and Gill, A. B. 2010. Environmental and Ecological Effects of Ocean Renewable Energy Development: A Current Synthesis. *Oceanography*, 23(2), 68-81. *https://tethys.pnnl.gov/publications/environmental-ecological-effects-ocean-renewable-energy-development-current-synthesis*

Brims Tidal Array Environmental Statement. 2016. *https://tethys.pnnl.gov/publications/brims-tidal-array-environmental-statement*

Copping, A. 2018. The State of Knowledge for Environmental Effects: Driving Consenting/Permitting for the Marine Renewable Energy Industry. Report by Pacific Northwest National Laboratory for Ocean Energy Systems. *https://tethys.pnnl.gov/publications/state-knowledge-environmental-effects-driving-consentingpermitting-marine-renewable*

Copping, A., Freeman, M., Gorton, A., and Hemery, L. 2020a. Risk Retirement—Decreasing Uncertainty and Informing Consenting Processes for Marine Renewable Energy Development. *Journal of Marine Science and Engineering*, 8(3), 21. doi:10.3390/jmse8030172 *https://tethys.pnnl.gov/publications/risk-retirement-decreasing-uncertainty-informing-consenting-processes-marine-renewable*

Copping, A., Freeman, M., and Overhus, D. 2020b. Risk Retirement for Environmental Effects of Marine Renewable Energy (Report No. PNNL-29996). Report by Pacific Northwest National Laboratory, Richland, Washington. *https://tethys.pnnl.gov/publications/risk-retirement-environmental-effects-marine-renewable-energy*

Copping, A., Gorton, A., and Freeman, M. C. 2018. Data Transferability and Collection Consistency in Marine Renewable Energy (Report No. PNNL-27995). Report by Pacific Northwest National Laboratory, Richland, Washington. *https://tethys.pnnl.gov/publications/data-transferability-collection-consistency-marine-renewable-energy*

Copping, A., Gorton, A., Freeman, M., Rose, D., and Farr, H. 2020c. Data Transferability and Collection Consistency in Marine Renewable Energy: An Update to the 2018 Report (Report No. PNNL-27995 Rev. 1). Report by Pacific Northwest National Laboratory, Richland, Washington. *https://tethys.pnnl.gov/publications/data-transferability-collection-consistency-marine-renewable-energy-update-2018-report*

Copping, A., Sather, N., Hanna, L., Whiting, J., Zydlewski, G., Staines, G., Gill, A., Hutchison, I., O'Hagan, A., Simas, T., Bald, J., Sparling, C., Wood, J., and Masden, E. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report by Pacific Northwest National Laboratory for Ocean Energy Systems. *https://tethys.pnnl.gov/publications/state-of-the-science-2016*

Cruz, E., Simas, T., and Kasanen, E. 2015. Discussion of the Effects of the Underwater Noise Radiated by a Wave Energy Device - Portugal. Paper presented at the 11th European Wave and Tidal Energy Conference, Nantes, France. *https://tethys.pnnl.gov/publications/discussion-effects-underwater-noise-radiated-wave-energy-device-portugal*

Electric Power Research Institute (EPRI). 2013. EPRI Workshop on EMF and Aquatic Life. Palo Alto, California. *https://tethys.pnnl.gov/publications/epri-workshop-emf-aquatic-life*

European Marine Energy Centre (EMEC). 2019. Marine Mammal Recording SOP074: Protocol for mitigation of marine mammal disturbance and injury at EMEC test sites. Report by European Marine Energy Centre, Orkney, Scotland. *https://tethys.pnnl.gov/publications/protocol-mitigation-marine-mammal-disturbance-injury-emec-test-sites*

European Technology and Innovation Platform for Ocean Energy (ETIP Ocean). 2017. Minimising negative environmental impacts. Webinar conducted by ETIP Ocean. *https://tethys.pnnl.gov/publications/etip-ocean-webinar-minimising-negative-environmental-impacts*

Farcas, A., Thompson, P. M., and Merchant, N. D. 2016. Underwater noise modelling for environmental impact assessment. *Environmental Impact Assessment Review*, 57, 114-122. doi:10.1016/j.eiar.2015.11.012 *https://tethys.pnnl.gov/publications/underwater-noise-modelling-environmental-impact-assessment*

Freeman, M., Copping, A., Gorton, A., and Dreyer, S. 2018. Managing Environmental Effects of Marine Renewable Energy Development through Regulator Engagement, Data Transferability. Paper presented at the Marine Energy Technology Symposium, Washington, D.C. *https://tethys.pnnl.gov/publications/managing-environmental-effects-marine-renewable-energy-development-through-regulator*

Hafla, E., Johnson, E., Johnson, C. N., Preston, L., Aldridge, D., and Roberts, J. D. 2018. Modeling underwater noise propagation from marine hydrokinetic power devices through a time-domain, velocity-pressure solution. *The Journal of the Acoustical Society of America*, 143(6), 3242-3253. doi:10.1121/1.5039839 *https://tethys.pnnl.gov/publications/modeling-underwater-noise-propagation-marine-hydrokinetic-power-devices-through-time*

Haikonen, K., Sundberg, J., and Leijon, M. 2013. Characteristics of the Operational Noise from Full Scale Wave Energy Converters in the Lysekil Project: Estimation of Potential Environmental Impacts. *Energies*, 6(5), 2562-2582. doi:10.3390/en6052562 *https://tethys.pnnl.gov/publications/characteristics-operational-noise-full-scale-wave-energy-converters-lysekil-project*

Hutchison, Z., Sigray, P., He, H., Gill, A., King, J., and Gibson, C. 2018. Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables (OCS Study BOEM 2018-003). Report by University of Rhode Island for Bureau of Ocean Energy Management, U.S. Department of the Interior, Sterling, Virginia. *https://tethys.pnnl.gov/publications/electromagnetic-field-emf-impacts-elasmobranch-shark-rays-skates-american-lobster*

International Electrotechnical Commission (IEC). 2019. Marine energy - Wave, tidal and other water current converters - Part 40: Acoustic characterization of marine energy converters (IEC TS 62600-40:2019). *https://tethys.pnnl.gov/publications/acoustic-characterization-marine-energy-converters-iec-ts-62600-402019*

Kavet, R., Wyman, M. T., and Klimley, A. P. 2016. Modeling Magnetic Fields from a DC Power Cable Buried Beneath San Francisco Bay Based on Empirical Measurements. *PLoS ONE*, 11(2), e0148543. doi:10.1371/journal.pone.0148543 *https://tethys.pnnl.gov/publications/modeling-magnetic-fields-dc-power-cable-buried-beneath-san-francisco-bay-based*

Korpinen, S., and Andersen, J. H. 2016. A Global Review of Cumulative Pressure and Impact Assessments in Marine Environments. *Frontiers in Marine Science*, 3(153). doi:10.3389/fmars.2016.00153 *https://tethys.pnnl.gov/publications/global-review-cumulative-pressure-impact-assessments-marine-environments*

Lepper, P. A., and Robinson, S. P. 2016. Measurement of Underwater Operational Noise Emitted by Wave and Tidal Stream Energy Devices. In A. N. Popper and A. Hawkins (Eds.), The Effects of Noise on Aquatic Life II (pp. 615-622), Springer: New York, New York. *https://tethys.pnnl.gov/publications/measurement-underwater-operational-noise-emitted-wave-tidal-stream-energy-devices*

Lossent, J., Gervaise, C., Iorio, L. D., Folegot, T., Clorennec, D., and Lejart, M. 2017. Underwater operational noise level emitted by a tidal current turbine and its potential impact on marine fauna. *The Journal of the Acoustical Society of America*, 141(5), 3923-3923. doi:10.1121/1.4988869 *https://tethys.pnnl.gov/publications/underwater-operational-noise-level-emitted-tidal-current-turbine-its-potential-impact*

Lossent, J., Lejart, M., Folegot, T., Clorennec, D., Di Iorio, L., and Gervaise, C. 2018. Underwater operational noise level emitted by a tidal current turbine and its potential impact on marine fauna. *Marine Pollution Bulletin*, 131, 323-334. doi:10.1016/j.marpolbul.2018.03.024 *https://tethys.pnnl.gov/publications/underwater-operational-noise-level-emitted-tidal-current-turbine-its-potential-impact*

Love, M. S., Nishimoto, M. M., Clark, S., McCrea, M., and Bull, A. S. 2017. Assessing potential impacts of energized submarine power cables on crab harvests. *Continental Shelf Research*, 151, 23-29. doi:10.1016/j.csr.2017.10.002 *https://tethys.pnnl.gov/publications/assessing-potential-impacts-energized-submarine-power-cables-crab-harvests*

Marine Scotland. 2015. SME Marine Licence Number 05684/15/0. Aberdeen, Scotland. *https://www2.gov.scot/Resource/0049/00493389.pdf*

Meißner, K., Schabelon, H., Bellebaum, J., and Sordyl, H. 2006. Impacts of Submarine Cables on the Marine Environment - A Literature Review. Institute of Applied Ecology, Broderstorf, Germany. *https://tethys.pnnl.gov/publications/impacts-submarine-cables-marine-environment-literature-review*

National Academies of Sciences, Engineering, and Medicine (NAS). 2018. Guidelines for Managing Geotechnical Risks in Design–Build Projects. Research Report 884. The National Academies Press, Washington, D.C. *https://tethys.pnnl.gov/publications/guidelines-managing-geotechnical-risks-design-build-projects*

National Marine Fisheries Service (NMFS). 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. NOAA Technical Memorandum NMFS-OPR-59. Report by National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Silver Spring, MD. *https://tethys.pnnl.gov/publications/2018-revisions-technical-guidance-assessing-effects-anthropogenic-sound-marine-mammal*

Nemeth, M., Priest, J., and Patterson, H. 2014. Assessment of Fish and Wildlife Presence Near Two River Instream Energy Conversion Devices in the Kvichak River, Alaska in 2014. Report by LGL Alaska Research Associates for Gray Stassel Engineering, Inc., Anchorage, Alaska. *https://tethys.pnnl.gov/publications/assessment-fish-wildlife-presence-near-two-river-instream-energy-conversion-devices*

Paboeuf, S., Macadré, L.-M., and Yen Kai Sun, P. 2016. A French Application Case of Tidal Turbine Certification. Paper presented at the 35th International Conference on Ocean, Offshore and Arctic Engineering, Busan, South Korea. doi:10.1115/OMAE2016-54834 *https://tethys.pnnl.gov/publications/french-application-case-tidal-turbine-certification*

Robertson, F., Wood, J., Joslin, J., Joy, R., and Polagye, B. 2018. Marine Mammal Behavioral Response to Tidal Turbine Sound. (Report No. DOE-UW-06385). Report by University of Washington for U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Washington D.C. doi:10.2172/1458457 *https://tethys.pnnl.gov/publications/marine-mammal-behavioral-response-tidal-turbine-sound*

Sabella. 2020. Sabella. Retrieved from *http://www.sabella-d10.bzh/*

Schmitt, P., Elsaesser, B., Coffin, M., Hood, J., and Starzmann, R. 2015. Field Testing a Full-Scale Tidal Turbine Part 3: Acoustic Characteristics. Paper presented at the 11th European Wave and Tidal Energy Conference, Nantes, France. *https://tethys.pnnl.gov/publications/field-testing-full-scale-tidal-turbine-part-3-acoustic-characteristics*

Schmitt, P., Pine, M. K., Culloch, R. M., Lieber, L., and Kregting, L. T. 2018. Noise characterization of a subsea tidal kite. *The Journal of the Acoustical Society of America*, 144(5), EL441-EL446. doi:10.1121/1.5080268 *https://tethys.pnnl.gov/publications/noise-characterization-subsea-tidal-kite*

Sherwood, J., Chidgey, S., Crockett, P., Gwyther, D., Ho, P., Stewart, S., Strong, D., Whitely, B., and Williams, A. 2016. Installation and operational effects of a HVDC submarine cable in a continental shelf setting: Bass Strait, Australia. *Journal of Ocean Engineering and Science*, 1(4), 337-353. doi:10.1016/j.joes.2016.10.001 *https://tethys.pnnl.gov/publications/installation-operational-effects-hvdc-submarine-cable-continental-shelf-setting-bass*

Tetra Tech. 2013. Underwater Acoustic Modeling Report - Virginia Offshore Wind Technology Advancement Project (VOWTAP). Report by Tetra Tech Inc. for Dominion Energy, Glen Allen, Virginia. *https://tethys.pnnl.gov/publications/underwater-acoustic-modeling-report-virginia-offshore-wind-technology-advancement*

Thomsen, F., Gill, A., Kosecka, M., Andersson, M., André, M., Degraer, S., Folegot, T., Gabriel, J., Judd, A., Neumann, T., Norro, A., Risch, D., Sigray, P., Wood, D., and Wilson, B. 2015. MaRVEN - Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy (Report No. RTD-K3-2012-MRE). Report by Danish Hydraulic Institute for European Union, Brussels, Belgium. *https://tethys.pnnl.gov/publications/marven-environmental-impacts-noise-vibrations-electromagnetic-emissions-marine*

Tougaard, J. 2015. Underwater Noise from a Wave Energy Converter Is Unlikely to Affect Marine Mammals. *PLoS ONE*, 10(7), e0132391. doi:10.1371/journal.pone.0132391 *https://tethys.pnnl.gov/publications/underwater-noise-wave-energy-converter-unlikely-affect-marine-mammals*

Vandendriessche, S., Derweduwen, J., and Hostens, K. 2015. Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. *Hydrobiologia*, 756(1), 19-35. doi:10.1007/s10750-014-1997-z *https://tethys.pnnl.gov/publications/equivocal-effects-offshore-wind-farms-belgium-soft-substrate-epibenthos-fish*

Westerberg, H., and Langenfelt, I. 2008. Sub-sea power cables and the migration behaviour of the European eel. *Fisheries Management and Ecology*, 15(5-6), 369-375. doi:10.1111/j.1365-2400.2008.00630.x *https://tethys.pnnl.gov/publications/sub-sea-power-cables-migration-behaviour-european-eel*

Wiesebron, L. E., Horne, J. K., and Hendrix, A. N. 2016. Characterizing biological impacts at marine renewable energy sites. *International Journal of Marine Energy*, 14, 27-40. doi:10.1016/j.ijome.2016.04.002 *https://tethys.pnnl.gov/publications/characterizing-biological-impacts-marine-renewable-energy-sites*

Woodruff, D., Schultz, I., Marshall, K., Ward, J., and Cullinan, V. 2012. Effects of Electromagnetic Fields on Fish and Invertebrates Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2011 Progress Report (Report No. PNNL-20813). Report by Pacific Northwest National Laboratory for U.S. Department of Energy, Washington D.C. *https://tethys.pnnl.gov/publications/effects-electromagnetic-fields-fish-invertebrates-task-213-effects-aquatic-organisms*

Wyman, M. T., Peter Klimley, A., Battleson, R. D., Agosta, T. V., Chapman, E. D., Haverkamp, P. J., Pagel, M. D., and Kavet, R. 2018. Behavioral responses by migrating juvenile salmonids to a subsea high-voltage DC power cable. *Marine Biology*, 165(8), 134. doi:10.1007/s00227-018-3385-0 *https://tethys.pnnl.gov/publications/behavioral-responses-migrating-juvenile-salmonids-subsea-high-voltage-dc-power-cable*

NOTES

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Copping, A.E., M.C. Freeman, A.M Gorton, and L.G. Hemery. 2020. Risk Retirement and Data Transferability for Marine Renewable Energy. 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. 262-278). doi:10.2172/1633208

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*

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