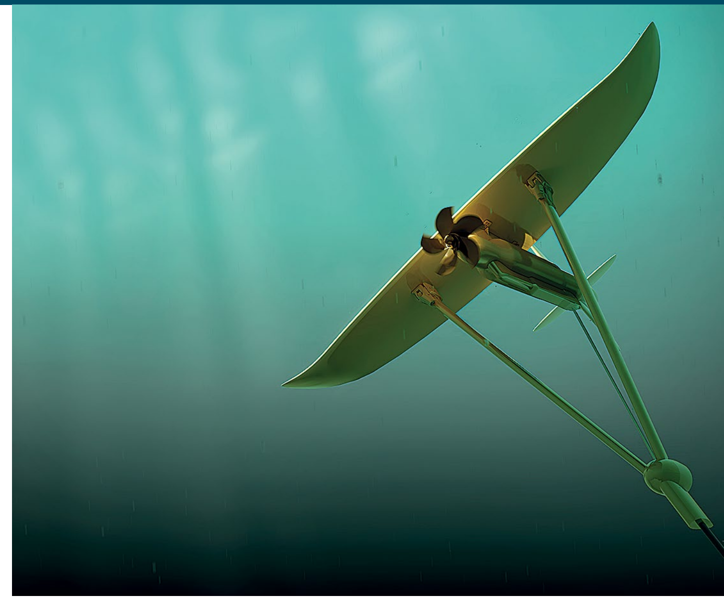
1.0



Chapter author: Andrea E. Copping

Marine Renewable Energy and Ocean Energy Systems

Research, development, and deployment of marine renewable energy (MRE) conversion technologies that harvest all forms of ocean renewable resources are being advanced around the world. The potential benefits derived from capturing the abundant energy of tides, waves, ocean currents, as well as thermal and salinity gradients, continue to drive the development of the emerging MRE industry. Stakeholder understanding of the potential benefits of MRE as a renewable energy source is informed by increased science-based understanding of the potential effects of MRE installations worldwide. The international Ocean Energy Systems (OES)-Environmental collaboration continues to promote global technology cooperation and information exchange to accelerate environmentally acceptable development of viable ocean energy systems.

1.1.
BENEFITS OF MARINE RENEWABLE ENERGY

The range of benefits that may be provided by the development and operation of MRE devices include the availability of a local secure energy source, potential economic development for local communities and regional supply chains, as well as mitigation for climate change. Additional detail on these benefits are explained further in Chapter 9 (Social and Economic Data Collection for Marine Renewable Energy), and some of the benefits of MRE in relation to other uses can be found in Chapter 11 (Marine Spatial Planning and Marine Renewable Energy). Other beneficial uses are sometimes considered, including improved ecological services and improvements to habitats.

Significant economic benefits can accrue from MRE development at a commercial scale, including the potential to enhance portions of coastal economies by creating high-paying skilled jobs in areas where other industries are not prevalent (Marine Energy Wales 2020; Smart and Noonan 2018).

Because MRE devices must be fully marinized, they may require relatively less maintenance compared to offshore wind turbine parts in air, although MRE devices may be placed farther offshore and in less hospitable regions, including in high latitudes and remote locations, which may increase the difficulty of maintenanc (Copping et al. 2018; LiVecchi et al. 2019). Relatively small MRE devices can be placed offshore to serve many different types of ocean observation platforms on the sea surface and at depth. This placement of devices alleviates the need for a surface presence and frequent costly vessel cruises to replenish batteries. It may also provide energy for emerging offshore aquaculture farms. These offshore devices could potentially provide a stepping stone to electrification of commercial shipping and passenger vessel trips (Copping et al. 2018; LiVecchi et al. 2019).

MRE has the potential to add to the renewable energy portfolios of many countries to meet low-carbon renewable energy standards (Copping et al. 2018; Thresher and Musial 2010) and to address the need for climate change mitigation (IRENA 2019; UN General Assembly 2012). Like solar and wind energy, MRE does not require that generation technologies be replenished with fossil fuels, which reduces risk to waterways or habitats from spills during transport or power generation, and does not cause air quality degradation. While the manufacture and other elements of the MRE life cycle will generate carbon emissions, these emissions are expected to be similar to those of other renewable technologies, which are accounted for in life cycle carbon budgets. However, processes for studying life cycle analyses for MRE are not well developed. Power generated from waves and tides is more predictable, consistent, and continuous than either wind or solar power.

Like other renewable energy forms, a driving motivation behind MRE development is the mitigation of climate change by reducing greenhouse gas (GHG) emissions through the expansion of non-carbon generating sources. Marine animals and plants are subject to the deleterious effects of GHG emissions-related ocean acidification (e.g., Doney et al. 2009; Fabry et al. 2008; Harley et al. 2006) and ocean warming (e.g., Cheung et al. 2013; Stachowicz et al. 2002; Wernberg et al. 2011), and nearshore habitats that support many commercially important and endangered species are affected by rising sea levels (e.g., Bigford 2008; Yang et al. 2015). The potential benefits to marine animals and habitats of mitigating climate change through renewable power generation far outweigh the potential impacts of MRE development, if projects are sited and scaled in an environmentally responsible manner (Copping et al. 2016). However, the scale of MRE development will need to be greatly accelerated in order to have a measurable effect on climate change mitigation and other benefits to marine life.

The placement of all wave and tidal devices developed to date requires contact with the seabed to hold them in place, either by gravity foundations placed on the seafloor, or some form of anchor or holdfast driven into the sea bottom. This placement will alter the immediate deployment location to some extent, but may also create new habitat types that may be in short supply in the immediate region. MRE devices (particularly wave energy converters [WECs]) can be sited offshore in ways that avoid rare rocky reef or deep-sea sponge/coral habitats, and they can be preferentially placed in soft-bottom habitats that are extensive on the continental shelves and slopes of the world's oceans. Adding an MRE foundation or anchor may create new hard-bottom habitat, providing shelter and access to food for benthic organisms (e.g., Callaway et al. 2017), including commercially important species like crab and lobster (Hooper and Austen 2014; Langhamer and Wilhelmsson 2009).

Typically, environmental statutes and regulations do not have mechanisms to enable consideration of beneficial uses of MRE devices—such as habitat creation (e.g., Callaway et al. 2017)—to offset potential deleterious effects. However, the creation of *de facto* marine reserves around MRE projects is likely to benefit local communities of fish and other organisms, as stressors associated with human activities, such as fishing, and disturbance are removed (Inger et al. 2009).

1.2. BALANCING CONCERNS WITH BENEFITS FOR MRE DEVELOPMENT

When considering the benefits of marine energy, one must also consider its potential negative effects. In every location where MRE development is being considered, it is important to determine potential effects on marine animals, habitats, and the oceanographic systems that support them, and to use every effort to minimize or mitigate such damage. Many of the animal populations that reside in the energy-rich areas of the ocean are already under considerable stress from other human activities including shipping, fishing, waste disposal, and shoreline development (Crain et al. 2009). To achieve sustainable development it is important that the MRE industry not cause additional environmental stress and related damage. It is the examination of these stresses, their potential risks to the marine environment, and how these risks might be understood, placed in context, managed, and minimized, that are the major focuses of this report.

1.3. *2020 STATE OF THE SCIENCE* REPORT

This report builds on and serves as an update and a complement to the 2013 Final Report for Phase 1 of OES-Environmental (Copping et al. 2013) and the *2016 State of the Science* report (Copping et al. 2016). Its content reflects the most current and pertinent published information about interactions of MRE devices and associated infrastructure with the animals and habitats that make up the marine environment. It has been developed and reviewed by over 60 international experts and scientists from around the world as part of an ongoing effort supported by the OES collaboration that operates within the International Technology Cooperation Framework of the International Energy Agency (IEA).

The term MRE is used throughout this report to describe power generated by the movement and gradients of seawater and the run of the river flows of large rivers. Generating power from the ocean includes the use of other technologies, including offshore wind turbines, but this report is focused on devices that generate energy from seawater and from large rivers. Lessons learned from bottom-fixed or floating offshore wind development and discussions of similar environmental effects also are included when appropriate.

1.3.1. SOURCES OF INFORMATION

Information used for the *2020 State of the Science* report is publicly available, published work derived either from peer-reviewed scientific literature or reports published by researchers, developers, and government agencies—all of which represent the state of knowledge for the industry. Report topics include monitoring, baseline assessments, and investigations of environmental effects for specific MRE projects; research studies that support specific MRE projects or address environmental interactions broadly; and guidance and assessments commissioned by governments and regulatory bodies to assist with the responsible development of the industry. The chapter authors all have expertise in these fields and have considered the available information to create a coherent view of the state of evidence and knowledge, using their own expert judgment to interpret the work.

1.3.2. USES OF THE INFORMATION

The information gathered and analyzed for the *2020 State of the Science* report was compiled to help inform regulatory and research investigations about potential risks to marine animals, habitats, and oceanographic processes from tidal and wave installations. This information can also be used to assist MRE developers when considering design engineering, siting, operational strategies, and monitoring options for projects that minimize encounters with marine animals and/or diminish the effects if such encounters occur. Used in conjunction with site-specific knowledge, the information from this report may simplify and shorten the time to consent/permit (hereafter consent) deployments—from single devices through commercial arrays. The information brought together for analysis represents readily available, reliable information about environmental interactions with MRE devices. However, the analyses and the conclusions drawn are not meant to take the place of site-specific analyses and studies, direct consenting actions, or influence siting considerations in specific locations.

1.3.3 REPORT PURPOSE AND SCOPE

This report summarizes the current state of knowledge, science, and understanding related to the potential environmental effects that MRE devices and systems placed in the ocean may have on the marine animals that live there and the habitats that support them. MRE development worldwide is mostly focused on the generation of power from waves, tides, and some large rivers, but MRE also includes generation from ocean currents and from temperature and salinity gradients.

This report describes the potential interactions of MRE devices with the marine environment and the methods and approaches used to evaluate the level of risk and uncertainty associated with these potential interactions. It provides insights into management approaches that have the potential to facilitate the MRE industry's ability to establish this new renewable energy source while also protecting the marine environment and the people who rely on it for their livelihoods.

This report summarizes and facilitates access to the best available scientific evidence on the environmental effects of MRE. The value of this information will be realized as it is applied to consenting processes to enable increased and responsible deployment of devices. For some low risk stressors, consenting of single devices and small arrays should be possible based on the information provided in this report, including information from consented or deployed projects, from related research studies or from evidence from analogous offshore industries. For higher risk stressors, further evidence will be needed.

This report does not specifically address tidal barrages or tidal lagoons, which generate power from the change in water flow from high to low tides and back. Dam-like tidal barrages generally consist of turbines installed across the mouths of tidal rivers and bays that capture power as the tide ebbs and floods. This method of energy capture tends to cause widespread environmental damage to river mouths and estuaries (e.g., Retiere 1994). Tidal lagoons resemble tidal barrages but are placed in bays away from the mouths of rivers. Little is known about the potential environmental effects of tidal lagoons (e.g., Elliott et al. 2019). To date a number of tidal lagoon projects have been proposed but there are no active projects under development in Europe or North America.

This report is limited to the in-water and nearshore aspects of MRE development and does not address the potential effects of shoreside components, including cable landings, electrical infrastructure, and connections to national grids.

1.3.4. REPORT CONTENT AND ORGANIZATION

The *2020 State of the Science* report on the environmental effects of MRE development begins with a set of environmental questions that define investigations (Chapter 2) and continues with specific information about stressor/receptor interactions of importance (Chapters 3–9), delves into technologies for monitoring interactions with marine animals (chapter 10), addresses a series of management and planning measures that may assist with responsible MRE development (Chapters 11–13), and concludes with a potential path forward (Chapter 14). The chapter topics are summarized in Table 1.1.

Throughout the report, numerous wave, tidal, and river current projects and test sites are discussed. Offshore wind sites are also mentioned when the environmental information from those sites informs MRE issues. The physical location of each of these projects is shown in Figure 1.1 and additional site information is provided in Table 1.2.

1.4. OCEAN ENERGY SYSTEMS

Founded in 2001, OES[1] is an intergovernmental collaboration between countries that operates within a framework established by the IEA[2] in Paris, France. The framework features multilateral technology initiatives that encourage technology-related research, development, and demonstration (RD&D) to support energy security, economic growth, and environmental protec-

1 *https://www.ocean-energy-systems.org/*
2 *https://www.iea.org*

Table 1.1. Description of the chapter topics in the *2020 State of the Science* report.

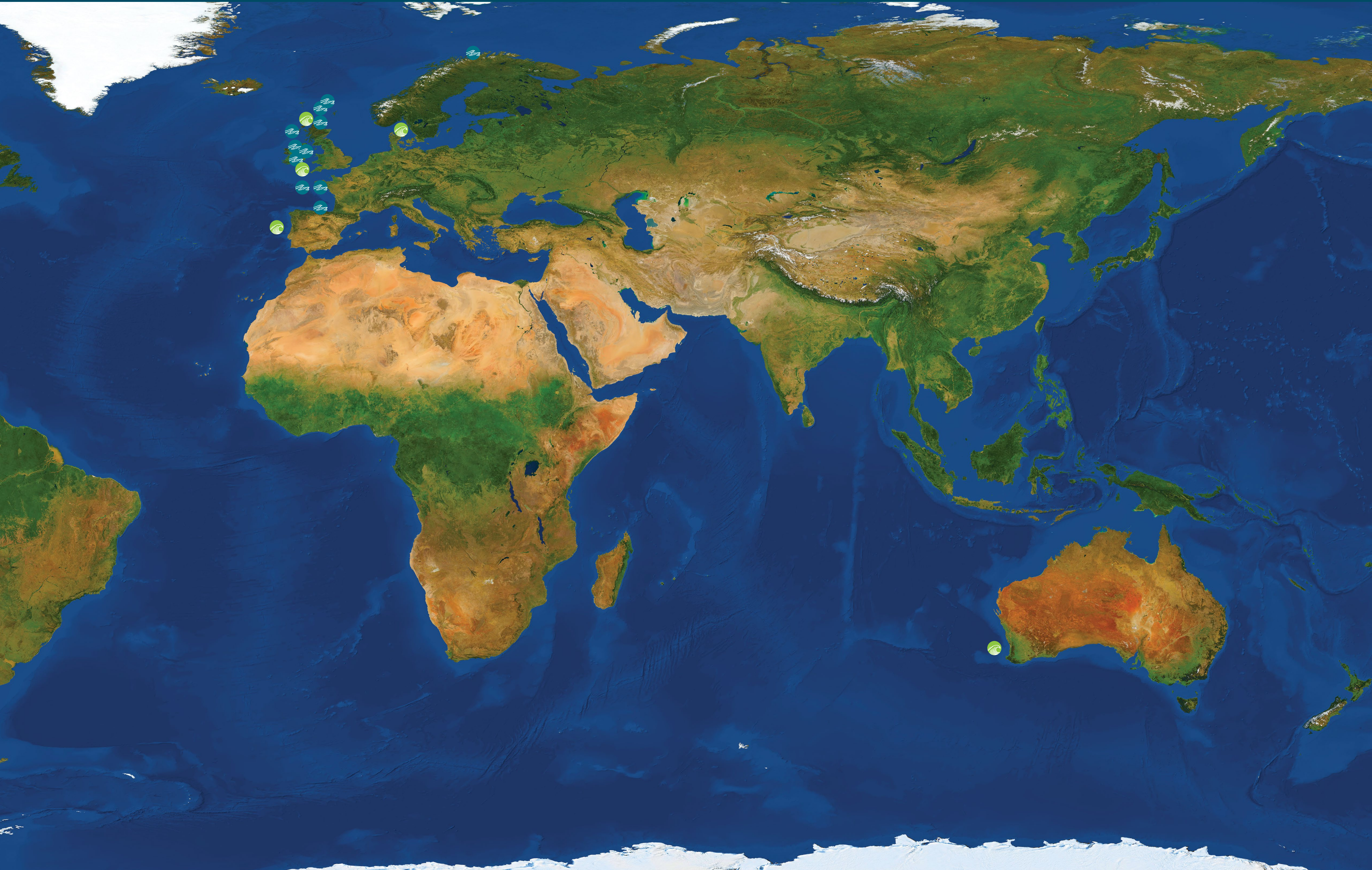
Chapter	Chapter Title	Topic
2	Marine Renewable Energy: Environmental Effects and Monitoring Strategies	Defining stressors and receptors, potential environmental effects, and approaches to monitoring marine renewable energy (MRE) interactions.
3	Collision Risk for Animals around Turbines	Research on collision risk for marine mammals, fish, and seabirds around turbines.
4	Risk to Marine Animals from Underwater Noise Generated by Marine Renewable Energy Devices	Research on the effects of underwater noise produced by operation of MRE devices on marine mammals and fish.
5	Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices	Research on the effects of electromagnetic fields produced by operation of MRE devices and transmission cables on sensitive marine species.
6	Changes in Benthic and Pelagic Habitats Caused by Marine Renewable Energy Devices	Research on the physical and biological changes to benthic and pelagic habitats caused by MRE devices.
7	Changes in Oceanographic Systems Associated with Marine Renewable Energy Devices	Research on the potential of MRE devices to change flow patterns, remove energy, and affect wave heights.
8	Encounters of Marine Animals with Marine Renewable Energy Device Mooring Systems and Subsea Cables	Research on the potential of marine animals to physically encounter, get entangled, or entrapped in mooring systems or cables from MRE devices.
9	Social and Economic Data Collection for Marine Renewable Energy	Data collection needs for addressing social and economic effects of MRE development for consenting.
10	Environmental Monitoring Technologies and Techniques for Detecting Interactions of Animals with Turbines	Research on existing environmental monitoring technologies and lessons learned from monitoring programs for turbines.
11	Marine Spatial Planning and Marine Renewable Energy	Marine spatial planning (MSP) interactions with MRE and possibilities for integrating MSP in planning and developing the MRE industry.
12	Adaptive Management Related to Marine Renewable Energy	Use of adaptive management in consenting MRE devices.
13	Risk Retirement and Data Transferability for Marine Renewable Energy	Potential for risk retirement and data transfer for consenting MRE devices, and a proposed pathway to streamline consenting processes.
14	Summary and Path Forward	Summary of the report and concluding remarks for a path forward.

tion. The Working Group for the OES Initiative advises the IEA Committee on Energy Research and Technology, which guides initiatives to shape work programs that address current energy issues.

Under the OES Initiative, countries, through international cooperation and information exchange, advance research, development, and deployment of conversion technologies to convert energy from all forms of ocean renewable resources, including tides, waves, currents, temperature gradients (ocean thermal energy conversion), and salinity gradients for electricity generation, as well as for other uses, such as desalination. OES comprises 24 member countries and the European Commission (as of May 2020), each of which is represented by a Contracting Party. The Contracting Party nominates representatives to the OES Executive Committee, which is responsible for the OES work program. Executive Committee participants are specialists from government departments, national energy agencies, research or scientific bodies, and academia.

The OES work program carried out by the Contracting Parties consists of research and development analysis, and information exchange related to ocean energy systems. Work is conducted on diverse research topics that are specified as tasks of the Implementing Agreement (the OES agreement among nations). Each task is managed by an Operating Agent, usually the member nation that proposes the initiative and undertakes a set of planned activities, engaging the other participating nations in all aspects of the work.

Figure 1.1. Tidal, wave, river current, and offshore wind sites mentioned in the various chapters of the report. See Table 1.2 for corresponding site information.




Alaska
1
Hawaii
5
Western United States
2
3
4
Eastern United States and Canada
6
7
8
9
10
Australia
26
United Kingdom
17
18
19
20
21
22
23
24
25
North Western Europe
11
12
Western Europe
13
14
15
16
Legend
Tidal
Wave
River
Offshore wind
Abandoned or decommissioned

Table 1.2. Wave, tidal, river current, and offshore wind sites mentioned in the various chapters of the report.

Site #	Site Name	Location	Technology	Project Name	Status
1	Kvichak River/Iguigig	Alaska, United States (U.S.)	River	ORPC RivGen	Operational
2	Race Rocks Ecological Reserve	British Columbia, Canada	Tidal Current Generator	Clean Current's Tidal	Decommissioned
3	Admiralty Inlet, Puget Sound	Washington, U.S.	Tidal Pilot Tidal Project	Admiralty Inlet	Abandoned
4	Reedsport	Oregon, U.S.	Wave	Reedsport OPT Wave Park	Abandoned
5	WETS	Hawaii, U.S.	Wave	Fred Olsen Lifesaver at WETS	Operational
6	Bay of Fundy	Nova Scotia, Canada	Tidal	FORCE test site, Cape Sharp Tidal Venture	Operational
7	Cobscook Bay	Maine, U.S.	Tidal	ORPC TidGen	Under Development
8	Grand Passage, Nova Scotia	Nova Scotia, Canada	Tidal	PLAT-I	Operational
9	Block Island	Rhode Island, U.S.	Offshore Wind	Rhode Island Ocean Special Area Management Plan	Operational
10	East River	New York, U.S.	Tidal	Roosevelt Island Tidal Energy (RITE)	Operational
11	Kvalsund	Norway	Tidal	Kvalsun Tidal Turbine Prototype (Hammerfest Strøm)	Decommissioned
12	Lysekil	Sweden	Wave	Lysekil Wave Energy Site	Operational
13	La Rance	France	Tidal Barrage	La Rance Tidal Barrage	Operational
14	Paimpol-Bréhat	France	Tidal	OpenHydro Paimpol-Bréhat Demonstration Project	Decommissioned
15	SEENOH Test Site	France	Tidal	Site Expérimental Estuarien National pour l'Essai et l'Optimisation Hydrolienne (SEENOH)	Operational
16	Aguçadoura	Portugal Wave Farm	Wave	Pelamis Wave Power Aguçadoura	Decommissioned
17	Bluemull Sound, Shetland	Scotland, United Kingdom (UK)	Tidal	Nova Innovation Shetland Tidal Array	Operational
18	Fall of Warness, Orkney	Scotland, UK	Tidal	EMEC test site	Operational
	Fall of Warness, Orkney	Scotland, UK	Tidal	OpenHydro at EMEC	Decommissioned
	Fall of Warness, Orkney	Scotland, UK	Tidal	EMEC test site: Deepgen, Alstrom	Decommissioned
19	Bllia Croo	Scotland, UK	Wave	EMEC test sit	Operational
20	Inner Sound, Pentland Firth	Scotland, UK	Tidal	MeyGen	Operational
21	Kyle Rhea	England, UK	Tidal	Kyle Rhea Tidal Stream Array	Abandoned
22	Strangford Lough	Northern Ireland, UK	Tidal	SeaGen	Decommissioned
	Strangford Lough	Northern Ireland, UK	Tidal	Minesto Powerkite	Decommissioned
	Schottel	Northern Ireland, UK	Tidal	Queen's University Belfast Tidal Test Site	Decommissioned
23	Holyhead Deep	Wales, UK	Tidal	Minesto Deep Green	Operational
24	Ramsey Sound	Wales, UK	Tidal	DeltaStream Pembrokeshire	Abandoned
25	FaBTest	Cornwall, UK	Wave	Fred Olsen Lifesaver at FaBTest	Decommissioned
26	Garden Island	Western Australia	Wave	Perth Wave Energy Project	Decommissioned

1.4.1. THE OES-ENVIRONMENTAL (FORMERLY ANNEX IV) TASK

The formation of the OES-Environmental[3] task or initiative, which is focused on the potential environmental impacts of MRE, was initiated by the United States and Canada in 2006 in response to a need for information about the environmental effects described in the summary of the IEA's meeting on ocean energy systems held in Messina, Italy (the Messina report).[4] After a meeting of experts in late 2007, the United States developed a proposal for the formalization of OES-Environmental (at that time called Annex IV), which was submitted to and approved by the OES Executive Committee in 2008. The proposal noted the need to compile and disseminate information about the environmental effects of MRE and to identify methods of monitoring for such effects. OES-Environmental was proposed to focus primarily on ocean wave, tidal, and current energy development. The phases of task activities and participation in OES-Environmental task since its initiation are described in Table 1.3. The task has been led by the United States with the U.S. Department of Energy acting as the Operating Agent and Pacific Northwest National Laboratory (PNNL) implementing the task on behalf of the United States.

1.4.2. OES-ENVIRONMENTAL PHASE 3

The workplan for OES-Environmental Phase 3 (2016–2020) built on the tasks carried out during Phases 1 and 2, and the current status of these plans is described in Table 1.4.

OES-Environmental also hosted several workshops during Phase 3, bringing together experts to advance understanding of key interactions and to work toward consensus on how research and monitoring information can help inform consenting processes and help to move the MRE industry forward. The workshops are listed in Table 1.5 below.

The culmination of Phase 3 of OES-Environmental is the preparation of this document, the *2020 State of the Science* report.

Table 1.3. Ocean Energy Systems (OES)-Environmental task phases, timeline, and participating countries. Information about OES-Environmental activities during Phases 1 and 2 are detailed in the *2016 State of the Science* report (Copping et al. 2016). The UUnited States (U.S.) has led all three phases of the task, with the U.S. Department of Energy acting as the Operating Agent and Pacific Northwest National Laboratory implementing the task.

Phase	Timeline	Nations and Partners Committed
Phase 1	2009 - 2012	Seven participating nations (Canada, Ireland, New Zealand, Norway, South Korea, Spain, and the United States [U.S.]) supported the Ocean Energy Systems (OES)-Environmental task by formalizing their commitments to the effort and developing a work plan and budget for the task. Cooperating U.S. federal agencies during this phase included the Federal Energy Regulatory Commission (FERC), the Bureau of Ocean Energy Management (BOEM), and National Oceanic and Atmospheric Administration (NOAA). Pacific Northwest National Laboratory (PNNL) was assisted by the Wave Energy Centre in Portugal and the University of Plymouth in the United Kingdom (UK).
Phase 2	2013 - 2016	Thirteen nations (Canada, China, Ireland, Japan, New Zealand, Nigeria, Norway, Portugal, South Africa, Spain, Sweden, the UK, and the U.S.) participated in Phase 2. Cooperating U.S. federal agencies during this phase included BOEM and NOAA. PNNL was assisted by Aquatera Ltd. in the UK.
Phase 3	2016 - 2020	Fifteen nations (Australia, Canada, China, Denmark, France, India, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, the UK, and the U.S.) participated in this phase. The leadership and implementation of the task remained the same as those during Phase 2.

3. OES-Environmental was known as Annex IV until August 2019, at which time the name was changed to be more in line with other OES tasks. The organization, mission, and management of the task has not changed.

4. National Renewable Energy Laboratory (U.S.) and Natural Resources Canada (Canada). October 18, 2007. Potential Environmental Impacts of Ocean Energy Devices: Meeting Summary Report.

Table 1.4. Workplan for Ocean Energy Systems (OES)-Environmental Phase 3 (2016-2020).

Task #	Task	Task Description	Status and Progress (as of May 2020)
1	Expand *Tethys* collection	Populate the publicly available knowledge management system *Tethys* *(https://tethys.pnnl.gov)* with scientific information about the environmental effects of marine energy.	◆ 6262 documents (of which 2996 are peer-reviewed) that address environmental effects of marine renewable energy (MRE) development on *Tethys*. ◆ Documents are continually added to *Tethys* as they become available.
2	Outreach and engagement	Outreach and engagement with the MRE community, with emphasis on researchers, regulators, and device developers.	Key activities pursued during this phase included the following: ◆ A biweekly electronic newsletter, *Tethys* Blast, has been sent to the Ocean Energy Systems (OES)-Environmental community of approximately 1800. All *Tethys* Blasts are archived on *Tethys* at *http://tethys.pnnl.gov/tethys-blasts*. ◆ Webinars with experts on environmental effects of MRE feature advances in research. All webinars have been archived on *Tethys* at: *https://tethys.pnnl.gov/environmental-webinars*. ◆ Expert forums are held to discuss difficult technical questions that are common to more than one jurisdiction and that are hindering consenting of MRE. Presentations and audio files are available on *Tethys* at: *http://tethys.pnnl.gov/expert-forums*.
3	Metadata forms on environmental monitoring	Compile information from environmental data collection and monitoring around deployed MRE devices and related research studies.	◆ 107 metadata forms related to marine energy deployments ◆ 106 metadata descriptions of research studies
4	Supporting international conferences	Partner with international conferences on MRE to raise the profile of environmental research on MRE.	◆ Environmental Interactions of Marine Renewables (EIMR) 2016, Edinburgh, United Kingdom (UK) February 2016. ◆ European Wave and Tidal Energy Conference (EWTEC) 2017, Cork, Ireland, September 2017. ◆ EIMR 2018, Orkney UK, April 2018. ◆ EWTEC 2019, Napoli, Italy, September 2019.
5	*State of Science*	Develop *2020 State of the Science* report for environmental effects of MRE.	◆ Research, write, and integrate extensive reviews for report. ◆ Release report as public draft, June 2020. ◆ Release final report, September 2020.

Table 1.5. Workshops held by Ocean Energy Systems (OES)-Environmental during Phase 3.

Title	Location	Date
Management Measures Workshop *https://tethys.pnnl.gov/events/management-measures*	Glasgow, United Kingdom (UK)	May 9, 2017
Exploring the State of Understanding and Practice used to Assess Social and Economic Risks and Benefits of Marine Renewable Energy Development *https://tethys.pnnl.gov/events/exploring-state-understanding-practice-used-assess-social-economic-risks-benefits-marine*	Cork, Ireland	Aug 31, 2017
Case Studies on Social and Economic Effects around MRE Developments *https://tethys.pnnl.gov/events/case-studies-social-economic-effects-around-mre-development*	Kirkwall, UK	Apr 23, 2018
Data Transferability and Collection Consistency Workshop (ICOE) *https://tethys.pnnl.gov/events/annex-iv-data-transferability-collection-consistency-icoe*	Cherbourg, France	Jun 12, 2018
Addressing Collision Risks from Tidal and River Turbines *https://tethys.pnnl.gov/events/addressing-collision-risks-tidal-and-river-turbines*	Edinburgh, UK	Feb 26, 2019
Retiring Risks of MRE Environmental Interactions to Support Consenting/Permitting *https://tethys.pnnl.gov/events/retiring-risks-mre-environmental-interactions-support-consentingpermitting*	Napoli, Italy	Sep 5, 2019
Retiring Risk for MRE Projects to Support Permitting *https://tethys.pnnl.gov/events/oes-environmental-workshop-retiring-risk-mre-projects-support-permitting*	Portland, Oregon, United States	Sep 11, 2019
Environmental Effects and Risk Retirement for MRE *https://tethys.pnnl.gov/events/oes-environmentalorjip-workshop-environmental-effects-risk-retirement-mre*	Sydney, Australia	Dec 4, 2019

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REPORT AND MORE INFORMATION

OES-Environmental 2020 State of the Science full report and executive summary available at:
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CONTACT

Andrea Copping
Pacific Northwest National Laboratory
andrea.copping@pnnl.gov
+1 206.528.3049

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