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WEST COAST ENVIRONMENTAL PROTOCOLS FRAMEWORK: BASELINE AND MONITORING STUDIES

FINAL REPORT

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by
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DISCLAIMER

This report is meant as a guide to both developers and regulators to facilitate the process of identifying pre-installation studies and post-installation monitoring protocols for a given offshore renewable energy project and technology type. These protocols, where they currently exist, are intended to standardize the way agencies and industry answer existing regulatory questions about the potential environmental effects of offshore renewable energy, and about the most appropriate way to monitor these effects. The West Coast Environmental *Protocols Framework* identifies standardized protocols, as well as protocols that need development, so that data are being collected across projects in a consistent manner and with a consistent format. Specifically, this report presents a stepwise approach to identifying monitoring needs, and where available, a series of standardized protocols to monitor the environmental effects of offshore renewable energy development on several groups of environmental resources and activities. The available protocols are presented alongside a process framework and series of thresholds and criteria designed to assist developers or regulators target study and monitoring needs based on the types of offshore renewable energy technology being used and on likely potential effects of development. This report describes a process framework and best practices for acquiring valid and comparable data in diverse field areas. The framework, thresholds, criteria and protocols contained within are intended as a menu of options for data collection from new offshore renewable energy projects, not as requirements, expectations or a to-do list for developers.

This report is not intended to supplant existing federal or state authority to determine what studies should be conducted, what protocols will be used or what monitoring should be required in order to issue a permit for any form of offshore renewable energy development. The requisite documents pertaining to the National Environmental Policy Act, the Endangered Species Act, the Magnuson-Stevens Fishery Conservation and Management Act, and other federal and state laws and requirements as part of the leasing, licensing or permitting process must be approved by the respective federal and state agencies involved in leasing, licensing or permitting, as they have the ultimate determination in whether any proposed study or monitoring is acceptable. Decisions on pre-installation studies and/or post-installation monitoring will still need to be made on a site-specific basis to ensure studies and monitoring address important factors such as species of concern for reasons of conservation or human use, specific life cycle or critical habitat considerations, and other environmental factors, as well as incorporating project-specific spatial and temporal scales. The process framework, thresholds, criteria, and protocols presented are intended both to guide developers and support agency decision making.

Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

The companies referenced in this report were not involved in developing content, analysis, or conclusions. The project information presented in this report is based on the project team’s summary of existing public information available at the time of its drafting, and is not endorsed by any company to be representative of any current or planned project.

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EXECUTIVE SUMMARY

The overarching goal of this West Coast Environmental *Protocols Framework* is to describe a clear, consistent process for regulators and industry to follow when designing environmental baseline and post-installation monitoring studies for proposed wave, tidal and offshore wind projects along the U.S West Coast, thus reducing time and uncertainty associated with project development. The use of the term *environmental* in the context of this report refers specifically to natural resources and ecological issues, not to human resources or socioeconomic or cultural issues. The project will describe a step-wise approach to identify monitoring protocols for developing wave, tidal and offshore wind ocean renewable energy projects. Common protocols will provide clarity and consistency in study requirements, which presently differ substantially between projects and regions. The specific objectives of the project are to:

- Identify and prioritize potential environmental issues to be monitored;
- Develop a screening tool (the protocols framework) for renewable ocean energy projects that can be used to identify baseline and effects information and protocols needed to collect that information;
- Address environmental thresholds, both scientific and regulatory, and related criteria in the framework;
- Screen the environmental issues and design the protocols framework, focusing on the California Current Large Marine Ecosystem (LME) and with intended portability to other LMEs;
- Obtain and consider information on emerging environmental monitoring protocols for ocean renewable energy development from Europe;
- Verify the proof of concept for the framework through case studies of wave, offshore wind and tidal projects on the U.S. West Coast;
- Vet the resulting products and process with a broad stakeholder group representing industry, regulators, scientists, environmental nongovernmental organizations, and industry; and
- Provide process recommendations for the possible adoption of this work into the state and federal regulatory processes to allow for consistency.

The protocols framework may be used to identify protocols that are applicable to a specific project and areas where additional protocol development is likely needed. The protocols framework may serve as a point of departure for discussions between ocean energy industry proponents and regulatory agencies.

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

This project is supported by the U.S. Bureau of Ocean Energy Management (BOEM), the U.S. Department of Energy (DOE), and the National Oceanic and Atmospheric Administration (NOAA), through the National Oceanographic Partnership Program.

PRIORITIES FOR PROTOCOLS DEVELOPMENT

This project is based on setting priorities for environmental issues that are likely to be the focus of ocean energy monitoring needs. The interaction of stressors (those parts of an ocean energy technology and/or project that may cause stress on the marine environment) and receptors (marine plants or animals, habitats, or ecosystem processes) is used to describe the environmental issues of concern. The study team identified eight generic environmental stressors (e.g., noise) across 18 generic environmental receptors (e.g., resident fish) for a total of 144 possible stressor–receptor interactions. These interactions were screened by separate subteams for wave, offshore wind, and tidal energy, and from three different perspectives—scientific expert opinion, regulatory requirements, and stakeholder opinion—resulting in a total of 1,296 possible integrated rankings. Each interaction was ranked as high, medium, low, or no interaction. The rankings for each perspective were integrated and scored based on a set of objective criteria, as described in the report. The primary input from the scientific expert opinion was derived from recent West Coast workshops on environmental effects of wave and tidal energy, and from European and Cape Wind project development experience for offshore wind. The regulatory rankings were highly influenced by species and habitats accorded special status under state and federal regulatory authorities such as the Endangered Species Act of 1973 (ESA). Stakeholder rankings reflected the interests and mandates of the individuals responding. Overall, high levels of uncertainty about an interaction tended to increase the ranking to a higher priority. When conflicting rankings were accorded to a stressor–receptor interaction, the scientific expert opinion was given the greatest weight. Minor nuances in the scoring are explained in the text.

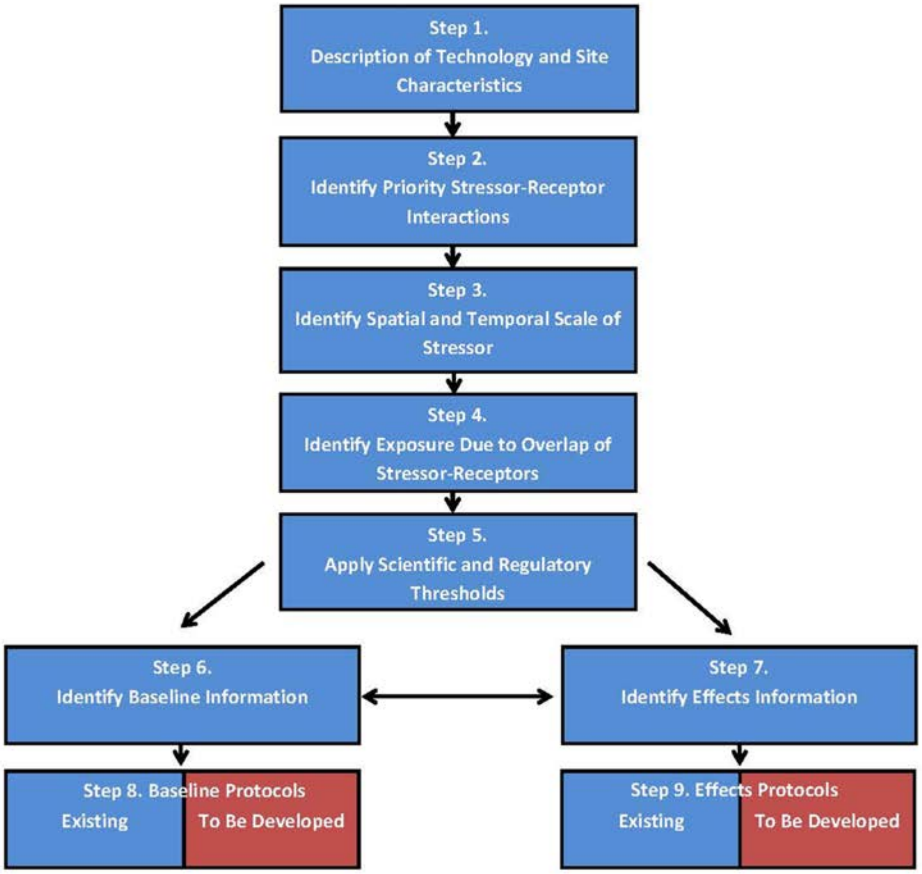
Of the 144 possible stressor–receptor interactions, the number of integrated priorities ranked medium or high totaled 41 for wave energy, 29 for tidal energy, and 32 for offshore wind energy. The greater number of high-priority interactions for wave energy reflects the diversity of wave energy conversion technologies now being developed and the uncertainty associated with the related environmental stressors.

Across technologies, the environmental stressor with the largest number of high- and medium-priority rankings was the presence of static devices, reflecting the variety of new interactions that could occur when new structures are introduced in open waters. Moving devices had more interactions for wave and tidal energy, whereas moving devices for offshore wind energy would be likely to interact only with bats and birds. Noise, vibration, and electromagnetic fields (EMF) were important across all three of the energy technologies, due largely to the uncertainty of effects associated with these stressors. Across the three energy technologies, the environmental receptors with high-and medium-priority rankings tend to favor groups with special regulatory status, including resident and migratory fishes, birds, and marine mammals.

THE PROTOCOLS FRAMEWORK

The West Coast Environmental *Protocols Framework* is a tool designed to screen renewable energy technologies and environmental site characteristics in order to identify needed baseline and effects information and applicable monitoring protocols (Figure E-1). The framework tool will assist in determining the protocols needed for industry to carry out environmental studies. The framework is a nine-step screening tool, beginning in Step 1 with a description of the technology to be used and the site where it is to be deployed. A description of the technology is necessary to identify the stressors that will be introduced into the ocean environment; greater detail of the technology will allow more specificity of the potential environmental stressors. Similarly, identifying the receptors that may be affected by an ocean energy development will help determine potential environmental effects. The receptors may include biological resources expected to be present at the site, such as individuals or populations, communities, habitats, or ecological processes, or physical attributes and dominant processes at the site, including ocean currents, seabed slope, and bottom sediment type. Specific information about the potential development site also allows for assessment of the physical attributes and dominant processes at the site.

Figure E-1. The ocean renewable energy *Protocols Framework*, described step-by-step in the text.



Steps 2 through 5 focus the potential scope of environmental interactions to identify specific information needs. The remaining steps identify the information needed to establish baseline conditions (Step 6), the **i**nformation needed to measure the effects of a stressor on a receptor (Step 7), and the protocols to collect that baseline (Step 8) and effects (Step 9) information, respectively. Although the framework is conceptually and visually simple, it can provide project-specific output (s).

THE CASE STUDIES

Case studies of real and hypothetical ocean renewable energy projects were used as the proof of concept for this project and to test the framework's utility. The project team evaluated all stressor–receptor interactions and developed a simple set of criteria to select a set of interactions that would provide the most meaningful test and evaluation of the protocols framework for each technology type. Fourteen interactions were selected, including five each for wave and tidal energy and four for offshore wind energy. Each interaction is a complete evaluation through the framework process.

The three case studies are scoped as commercial-scale projects. The wave case study is based on a proposed project under development off Reedsport, Oregon, using 10 Ocean Power Technologies PowerBuoys®. The tidal case study is based on a pilot-scale tidal project under development in Admiralty Inlet, Puget Sound, Washington, two six-meter OpenHydro turbines; for the case study we postulated a hypothetical commercial scale deployment of 20-40 10-meter turbines. The offshore wind energy case study is based on a hypothetical project using a commercial build-out of 25 Principle Power WindFloat® wind turbines offshore of Humboldt Bay, California, near a site that had been considered for a wave energy project.

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Each case study applied the framework as it is intended for use in the context of an ocean energy project, and generated a table that detailed how the framework was applied that is accompanied by a narrative describing the case. Specific information about the technology and site was used to assess the spatial and temporal overlap of the stressor and receptor in order to estimate exposure. Application of scientific and regulatory thresholds allowed for an assessment of the information needs for baseline and effects monitoring. At this point, monitoring protocols to evaluate specific interactions were selected. In some cases, several existing protocols were found that address the information needs; the advantages and disadvantages of the existing protocols were compared to help select the best protocol for a particular situation.

The case studies are highly detailed. Each is a stand-alone example of the protocols framework application highlighting the differences between the technologies, project sites and demonstrating the need to tailor individual protocols for a specific development project.

CONCLUSIONS

This project has resulted in three major conclusions. The first conclusion concerns the identification of priorities for monitoring potential environmental effects. Design and application of the framework resulted in a priorities list for each type of ocean energy technology (wave, tidal, and offshore wind), based on the consideration of the interaction of environmental stressors and receptors by scientific subject matter experts, regulatory requirements, and stakeholder opinion. The study team believes, and the subject matter experts agree, that the priorities identified include the environmental interactions that will most likely require baseline and/or effects monitoring for the siting and permitting or licensing of actual projects. However, the setting of priorities among these issues may change, depending on the specific technology and location, with the acquisition of new or more accurate data on environmental effects or with changes in regulatory status, such as the listing or delisting of species or habitats that are provided special protections. The information derived from applying the protocols framework can help to inform future projects and will begin to provide a useful record of investigating and resolving environmental issues associated with ocean energy development.

The second major conclusion concerns the applicability of the framework tool. The case studies have verified the proof of concept and demonstrated the utility of the framework for hypothetical and actual projects. Given increasing specificity about the environmental stressors accompanying a given technology, and the deployment of that technology at a specific site, the framework can successfully screen many potential environmental issues to identify those that require substantial monitoring and specific baseline or effects protocols. Further, the general applicability of the priorities for protocols development, the case studies, the team reviews of European protocols, and the subject matter expert reviews suggest that this framework should be portable across ocean renewable energy projects sited in the United States. However, the ability of the screening tool to deliver specifically applicable protocols or information needs depends on the specificity of the information available about the technology and its stressor characteristics as well as populations, communities, and habitats at the project site.

The third major conclusion of this study concerns the adaptability of protocols that are portable across differing technologies but are still specific enough to be useful at a single site. The marine environment is highly variable across time and space, which results in high variability in organism densities across days or months and across mesoscale distances (i.e., kilometers to tens of kilometers), and strong variability in physical conditions that can affect deployment of sampling technologies. Such variability is likely to determine the sampling density required to demonstrate a given level of change. A user of the framework can expect to fine-tune or adapt a selected protocol to the existing conditions at his/her project site.

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LIST OF ACRONYMS AND ABBREVIATIONS

ac – Acres

AC – Alternating Current

ACI – After-Control-Impact

BACI – Before-After-Control-Impact

BOEM – Bureau of Ocean Energy Management

BSH – Bundesamt für Seeschifffahrt und Hydrographie

BWEA – British Wind Energy Association

CCLME – California Current Large Marine Ecosystem

CEFAS – Centre for Environment, Fisheries & Aquaculture Science (United Kingdom)

CMSP – Coastal and Marine Spatial Planning

COWRIE – Collaborative Offshore Wind Research into the Environment

CPUE – Catch per Unit Effort

CWA – Clean Water Act

dB – Decibels

DC – Direct Current

DECC – Department for Energy and Climate Change (United Kingdom)

DEFRA – Department for Environment, Food and Rural Affairs (United Kingdom)

DPS – Distinct Population Segment

EFH – Essential Fish Habitat

EMAP – Environmental Mapping and Assessment Program (U.S. Environmental Protection Agency)

EMEC – European Marine Energy Centre

EMF – Electromagnetic Field

EPRI – Electric Power Research Institute

EquiMar – *Equit*able Testing and Evaluation of *Mar*ine Energy Extraction Devices in terms of Performance, Cost and Environmental Impact

ESA – Endangered Species Act

EU – European Union

EWEA – European Wind Energy Association

FAA – Federal Aviation Administration

FAD – Fish Attraction Device

FERC – Federal Energy Regulatory Commission

ft – Feet

FVCOM – Finite Volume Coastal Ocean Model

gal – Gallons

GPS – Global Positioning System

hr – Hours

IEA – Integrated Ecosystem Assessment

IUCN – International Union for Conservation of Nature

JNCC – Joint Nature Conservation Committee (United Kingdom)

kHz – KiloHertz

km – Kilometers

L - Liters

LME – Large Marine Ecosystem

LOAEL – Lowest observed adverse effect level

m – Meters

MBARI – Monterey Bay Aquarium Research Institute

MBTA – Migratory Bird Treaty Act

mi – Miles

mm - Millimeters

MMPA – Marine Mammal Protection Act

m/s – Meters per second

MSFCMA – Magnusen-Stevens Fishery Conservation and Management Act (also MSFA)

MW – Megawatts

NEPA – National Environmental Policy Act

NMFS – National Marine Fisheries Service; NOAA Fisheries

NNMREC – Northwest National Marine Renewable Energy Center (Oregon State University and University of Washington)

NOAA – National Oceanic and Atmospheric Administration

NOAEL – No observable adverse effect level

NOPP – National Oceanographic Partnership Program

NWR – National Wildlife Refuge

OPT – Ocean Power Technologies, Inc.

OSPAR Convention – Convention for the Protection of the Marine Environment of the North-East Atlantic (European Union)

OSU – Oregon State University

OSU CIMRS – Oregon State University Cooperative Institute for Marine Resources Studies

PDT – Protocols Development Team

PMT – Program Management Team

PNNL – Pacific Northwest National Laboratory (US Department of Energy)

PUD – Public Utility District

RNSP – Redwood National and State Parks

ROMS – Regional Ocean Modeling System

ROV – Remotely Operated Vehicle

rpm – Revolutions per minute

SAT – Stakeholder Advisory Team

SCUBA – Self Contained Underwater Breathing Apparatus

SEA – Strategic Environmental Assessment (United Kingdom)

SEA, Inc. – Southall Environmental Associates, Inc.

SME – Subject Matter Expert

SMRU – Sea Mammal Research Unit (University of St. Andrews)

SRKW – Southern Resident Killer Whale

SSF – Subsurface float

TBD – To Be Determined

TOC – Total Organic Carbon

UC – University of California

UNEP – United Nations Environment Progamme

µPa – microPascals

USCG – U.S. Coast Guard

USDOE – U.S. Department of Energy

USDOI – U.S. Department of the Interior

USEPA – U.S. Environmental Protection Agency

USFWS – U.S. Fish and Wildlife Service

1 INTRODUCTION

1.1 PROJECT PURPOSE

Through offshore wind, wave, and tidal forces, the oceans are continuously generating substantial amounts of energy that can greatly contribute to the domestic and global renewable energy supply. Due to the increasing global demand for renewable energy, many countries including the United States have begun to explore the possibilities of harnessing the energy generated from the world's oceans. For ocean energy development to proceed in the United States, the environmental mandates expressed in federal, state, local, and tribal statutes and regulations must be met, which presents several notable challenges and obstacles. One of these key challenges is the lack of knowledge concerning how renewable ocean energy devices affect the marine environment (U.S. DOE, 2009). For example, it is unclear how marine mammals will react to the physical presence of a moving tidal turbine blade, or how migratory fish may be affected by the electromagnetic forces emitted by offshore power cables, if at all.

To address these uncertainties, it is important to understand the spatial and temporal scales of the interactions between the proposed technologies and the marine ecosystem. Because a variety of technologies can be used to harness the ocean's energy, coupled with significant biological and physical complexity within ocean ecosystems, comprehending these interactions can be challenging. Bridging these complexities and satisfying the regulatory mandates that protect ocean resources requires the consistent collection of information through a system of accepted protocols for baseline assessment and post-installation effects monitoring.

The overarching goal of this project is to provide a consistent process for regulators and industry to follow when designing environmental baseline and post-installation monitoring studies for proposed wave, tidal and offshore wind projects in the United States. Specific protocols should be developed to assist in understanding these interactions; this report develops a standard *Protocols Framework* that will ensure information is collected in a consistent manner, allowing data to be used to inform multiple projects. We apply the *Protocols Framework* to three specific case studies that highlight the most practical and efficient means of measuring, assessing, permitting, and ensuring that the marine renewable energy industry is developed in an environmentally responsible manner.

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

1.2 PROJECT OVERVIEW

This report is intended for interested parties seeking information about ocean renewable energy development and potential environmental effects, including the renewable ocean energy industry, regulators, researchers, and stakeholders. The use of the term *environmental* in the context of this report refers specifically to natural resources and ecological issues (physical chemical and biological), not to human resources or socioeconomic or cultural issues.

The specific objectives of the project are to:

- Identify and prioritize potential environmental issues to be monitored;
- Develop a screening tool (the *Protocols Framework*) for renewable ocean energy projects that can be used to identify baseline and effects information and protocols needed to collect that information;
- Address environmental thresholds, both scientific and regulatory, and related criteria in the framework;
- Screen the environmental issues and design the protocols framework, focusing on the California Current Large Marine Ecosystem (LME) and with intended portability to other LMEs;
- Obtain and consider information on emerging environmental monitoring protocols for ocean renewable energy development from Europe;
- Verify the proof of concept for the framework through case studies of wave, offshore wind, and tidal projects on the U.S. West Coast;
- Vet the resulting products and process with a broad stakeholder group representing industry, regulators, scientists, environmental nongovernmental organizations, and industry; and
- Provide process recommendations for the possible adoption of this work into the state and federal regulatory processes to allow for consistency.

The project team used a stepwise approach to develop a tool termed the *Protocols Framework*. The tool is intended to screen stressor–receptor interactions for specific ocean renewable energy projects to determine what information is needed to support siting and permitting of those projects and define monitoring protocols to be used to collect that information where appropriate. The steps taken during the study are briefly described below. The project team refers to the personnel who worked on a particular part of the project and/or to specific task subgroups including the Protocols Development Team (PDT) and the Stakeholder Advisory Team (SAT). The team members are identified in the Acknowledgments section on pages iv-v.

1.3 ADDITIONAL CONSIDERATIONS

Overarching considerations were taken into account by the project team because they apply broadly to the process of developing the *Protocols Framework* and the case studies. These considerations briefly are discussed below.

1.3.1 European Protocols

Regulators and policy makers in Europe have recognized the need for national and international guidance and standard procedures (protocols) for developers and regulatory agencies to follow in the environmental permitting process for renewable ocean energy projects. The development of offshore wind has preceded that of wave and tidal energy development; guidance on the collection of environmental information and processes that entail the application of protocols reflect this greater focus on offshore wind. In creating a workable framework for U.S. protocols the progress made in Europe has been considered as important background information. Additional information is available in Appendix D.

1.3.2 Effects versus Impacts

When we evaluate the interaction of a renewable ocean energy technology with the marine environment, we generally undertake a pairwise comparison of stressors with receptors; the stressor might be a piece of the technology such as a turbine blade or wave buoy, the anchor or foundation, a mooring line, or the power cable, while the receptor is an animal, a habitat, or an ecosystem process. The interaction of a stressor–receptor pair can be measured along a continuum that ranges from no effect, through a limited effect, to an interaction that may have substantial consequence for the receptor, commonly known as an impact. Boehlert and Gill (2010) point out the important semantic distinction between *effect* and *impact*, and state the following: “The two terms are often used interchangeably, but “effect” does not indicate a magnitude or significance, whereas “impact” implicitly deals with severity, intensity, or duration of the effect. Furthermore, impact also deals with direction of effect, which means there can be positive or negative outcomes to the effect of the stressor.” Many studies can demonstrate an effect, but more rigorous analysis is required to identify an impact. Effects may be single or multiple, short term or long term, but may not be lasting in terms of environmental consequences. Impacts typically have more serious consequences, for example population changes (operating through direct mortality or effects on reproductive fitness), changes in communities, alterations to biotic or physical processes, or changes in physical structure of the environment.

In this report, the project team adopts this terminology and refers to stressor–receptor interactions that are likely to occur but have small or unknown consequence as *effects*, while the term *impacts* is reserved for interactions that are potentially of greater consequence. We focus on interactions that represent negative impacts; while positive impacts may occur, for example increased concentrations of forage fish around a wave buoy or offshore wind structure, there may be related consequences that are negative, for example the attraction of marine mammals or birds to those concentrations and thus exposure to greater interactions with the devices; therefore, we considered most positive impacts under the umbrella of ecosystem interactions.

1.3.3 Cumulative Effects

The effects of renewable ocean energy projects must be viewed in the context into which they are placed. Scientific investigations and regulatory mandates refer to the issue of cumulative effects, although the meaning and mode of measurement may differ. Although not explicitly examined in this project, stakeholders raised the issue of cumulative effects of renewable ocean energy projects, and the project team is mindful of its importance. *Cumulative effects* of renewable ocean energy refer to 1) the potential effects on the environment of multiple project stressors; 2) the potential effects associated with multiple renewable ocean energy projects within a geographic area; and 3) additive or multiplicative effect of adding renewable ocean energy to existing anthropogenic effects.

1.3.4 Attributes of Protocols

A protocol within the context of this project may be defined as a written, validated, and broadly accepted methodology for collection and/or analysis of scientific data to assess environmental baseline assessment or post-installation effects monitoring. Environmental monitoring protocols possess attributes that make them more or less useful across many stressor–receptor interactions, for different renewable ocean energy technologies, and in differing site locations. These attributes should be considered in choosing the most appropriate tools to address specific stressor–receptor interactions from among available protocols, as shown in the case studies.

1.3.5 Adoption of Protocols

As part of this analysis, the project team was asked to explore the ability to identify and adopt baseline and effects monitoring protocols relating to ocean energy development. The project team's collective experience indicated that generic monitoring protocols are not likely to be widely available because the ecological issues and ways to address them vary by both location and technology; Not only do issues vary, but the criteria and thresholds that make issues "matter" also vary.

Recognizing this challenge, the project team's primary focus was the development of the *Protocol Framework*, a scientific process of evaluation to identify and address the ecological effects of ocean energy development. The *Protocol Framework* is a useful first-step to identify what baseline and monitoring studies may be needed, what protocols exist and where additional protocols are likely needed.

Throughout the development of the *Protocol Framework* and associated case studies, the project team engaged with subject matter specialists and stakeholders. As part of the final review of the *Protocol Framework*, stakeholders were asked if they thought it was helpful or necessary for the *Protocol Framework* and the associated work to be formally adopted. Stakeholders indicated that the *Protocol Framework* is very useful in support their regulatory processes, *but that it was not necessary or appropriate for the Protocol Framework to be adopted.* Stakeholders suggested that the *Protocol Framework* should be a living document that could be updated as new information and new projects are developed in order to take advantage of best available practices as the industry develops over time.

It is the experience of the project team that there are a limited number of processes and protocols that are "officially" adopted in the scientific and regulatory communities. Most regulatory processes rely on best available science which involves review and analysis of all available information relative to the subject and, therefore, are constantly being updated. Study protocols are tested, evaluated, and adapted and evolve into best practices to meet the requirements of a study.

The *Protocol Framework* captures best available science and best practices based on current information and the technologies and locations identified. However, as indicated above, best available science and best practices change as new information and study results become available. For this reason, the project team supports the conclusion of the stakeholders that the Protocol Framework is best used as living document, and not one formally adopted.

To support the use of the Protocol Framework as a living document, the key outcomes of the Framework are identified below. For each key outcome, we included recommendations on how to use and update it over time to support the further development of best practices in the industry.

a) *Evaluation process for ecological issues* – The step by step process outlined in the Protocol Framework reflects best practices for identifying and evaluating ecological issues. The process is a scientific method for identification and evaluation of issues and, therefore, is not expected to change over time.

b) *Priority issues for monitoring*– This report identifies priority issues for monitoring for each ocean renewable energy technology. This identification was made based on best available science at the time of the report. As projects are deployed and/or baseline and monitoring studies are conducted, the summary and analysis of information could be updated. The list of priorities can be used as a reference point for projects of a similar nature. However, it is recognized that the specific technology and location will ultimately determine priority issues.

c) *Baseline and Monitoring Protocols* – The case studies are an application of the evaluation process using best available information. In addition, the case studies identify current protocols and needed protocols for the evaluation of baseline and effects information. The report is not an exhaustive list of protocols, but identifies monitoring protocols that are currently in active use and considered best practices by the subject matter experts and stakeholders. As projects are deployed and/or baseline and monitoring studies are conducted, the summary of current and needed protocols could be updated.

1.3.6 Renewable Ocean Energy Project Scale

Renewable ocean energy projects were examined at the commercial scale to generate the priorities for monitoring and protocols development (Chapter 3). The priority stressor–receptor interactions will generally be the same for pilot or commercial projects for a specific technology at the same site. However, the scale of data collection and monitoring needs may differ because the overall exposure of some receptors may be greater with commercial scale build-out. The scale and location of the project can be expected to influence the selection of monitoring techniques; some monitoring techniques may have statistical power to detect change only at the commercial scale.

Renewable ocean energy projects will require assessment and integration of monitoring needs across stressor–receptor interactions to evaluate monitoring costs and potential savings through combining monitoring efforts whenever possible. For example, aerial surveys may not be cost effective for monitoring stressor–receptor interactions for a single species but are likely to become cost effective for multiple species. The *Protocols Framework* does not address this analysis, but where synergies are obvious they are described in the case studies.

1.3.7 Adaptive Management Context

Adaptive management plays a key role in furthering the understanding and appropriate application of data collection for ocean energy projects; the *Protocols Framework* assumes the application of adaptive management principles (Williams et al. 2009). Gathering additional information on stressor-receptor interactions through monitoring and/or research studies is likely to reduce the uncertainty of the interaction. As the interactions become better known, it may become appropriate to reduce or discontinue effects monitoring for that interaction. Conversely, mandating a higher level of scrutiny or sampling density for a given interaction may become necessary. Effects data collected from each ocean energy project should help to informing adaptive management for other projects.

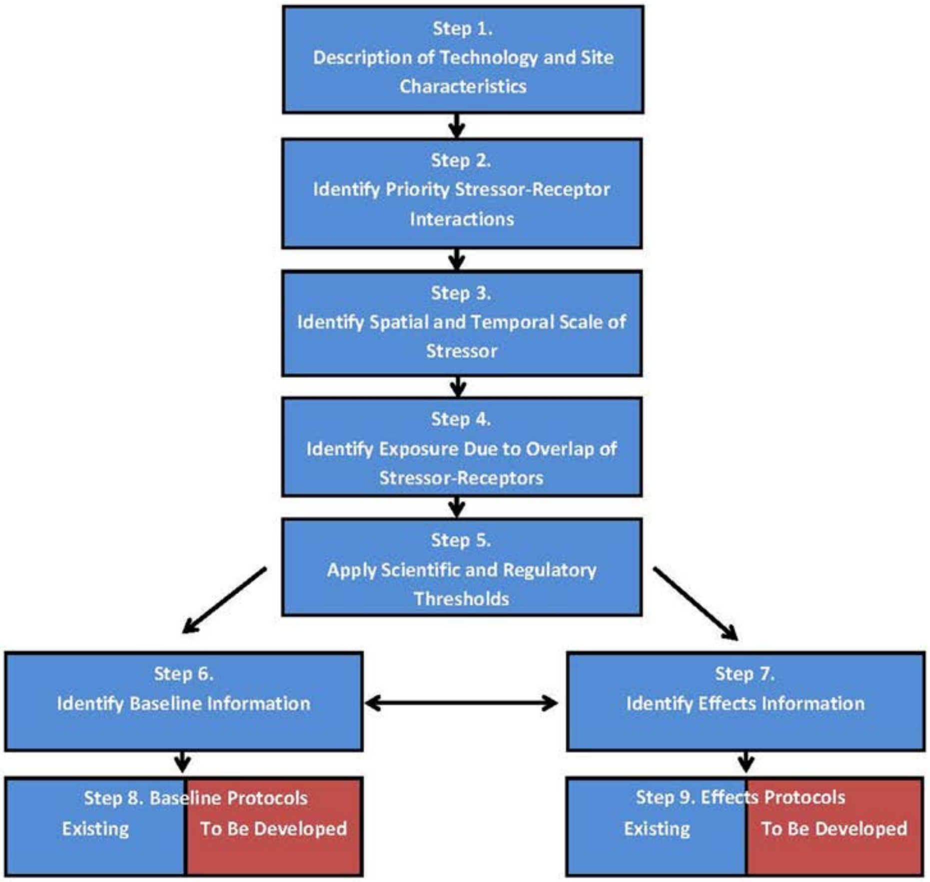
1.3.8 Additional Products

There are several additional components developed for this project that were used to aid the development of the framework included as appendices. Appendix C is a report on Criteria and Thresholds that provides support for determination of thresholds in Step 5 of the framework, and describes types of criteria necessary to develop the protocols that address the thresholds. Appendix D is a review of the environmental protocols that have been developed in Europe that were used to inform this project. Lastly, Appendix F is an analysis of the relationship between the Framework Protocols and the evolving state of Coastal Marine Spatial Planning (or Ocean Planning) in the U.S.

2 FRAMEWORK TOOL DESCRIPTION

The application of the environmental monitoring protocols framework tool is a stepwise process, beginning with the identification and general description of the ocean energy project and moving incrementally toward identifying the specific environmental monitoring protocols needed to measure environmental baseline and potential post-installation effects. This chapter defines each step in the framework and provides examples of the information to be gathered or considered at each of the steps for wave, tidal and offshore wind energy development projects. A broad view of the nine-step framework is provided in Figure 2-1.

Figure 2-1. The ocean renewable energy Protocols Framework, described step-by-step in the text.



2.1 STEP 1: DESCRIBE TECHNOLOGY AND SITE CHARACTERISTICS

The first step of the framework defines the proposed project and includes a description of the ocean energy technology, type of water body, project location, and general site characteristics including the organisms and habitats that can be expected to inhabit that location. The protocols framework relies on, at a minimum, a description of a technology type (wave, tidal, or offshore wind) and the setting and type of water body where it will be deployed.

A description of the technology is necessary to identify the stressors that will be introduced into the ocean environment; greater detail of the technology will allow more specificity of the potential environmental stressors. Stressors are any characteristic of the technology, physical or chemical, that may induce or cause a change in a feature or component of the environment (i.e., a receptor). The framework process can be used without identification of a specific technology type. However, the user will have a better understanding of priority issues and information needs as more information is provided about the technology.

Similarly, identifying the receptors of an intended ocean energy development site will help to determine the potential environmental effects. The receptors may include biological resources expected to be present at the site, such as individuals or populations of species, communities, habitats, or ecological processes; or physical attributes and dominant processes at the site, including ocean currents, seabed slope, and bottom sediment type. Specific information about the potential development site also allows for assessment of the physical attributes and dominant processes at the site. This information, combined with a preliminary list of the biological resources likely to be present, will help determine the potential environmental effects. Examples of the kinds of information needed for Step 1 for the three energy sources—wave, tidal and offshore wind—are shown in Table 2-1.

Table 2-1 Example of the kinds of information gathered for Protocols Framework for description of technology and site characteristics.

Wave	Wave energy converter, anchored with mooring lines in coastal continental shelf. Power cables from devices to power cable buried in sediment to shore. Soft-bottom habitat, migratory whales, migratory salmon and sturgeon, resident demersal fish, coastal crab populations, birds.
Tidal	Tidal turbines with gravity foundation. Individual power cables on bottom to shore. Hard-bottom habitat, migratory and resident whales, resident pinnipeds, migratory salmon, resident rockfish.
Offshore Wind	Wind turbines on floating platforms anchored with mooring lines on continental shelf off coast. Power cables from each turbine to cable buried in sediment to shore. Soft-bottom habitat, birds, bats, migratory whales, migratory and resident fish.

2.2 STEP 2: IDENTIFY PRIORITY STRESSOR - RECEPTOR INTERACTIONS

The intersections of the attributes of the proposed ocean energy project (i.e., its environmental stressors) and the receptors expected to be present at the project site define the possible environmental effects. These intersections are used to assess the potential environmental effects, as informed by existing information about the interaction of those stressors and receptors in the system. This step relies on the incorporation and evaluation of expert scientific opinion, existing environmental regulations, and stakeholder values.

In the development of the *Protocols Framework*, the project team developed a method for identifying and prioritizing interactions that are likely to require monitoring for each technology type. That process is reported in Chapter 3. This information can be used as a starting point for any user of the framework. A given user may want to update or amend the project team's analysis with new information and/or with more specific information about the stressors of a technology or receptors of a project site. Examples of the kinds of information needed for Step 2 for the three energy sources are shown in Table 2-2.

Table 2-2 Example of information gathered for Protocols Framework to identify priority stressors.

Wave	Interaction of wave energy converter, anchor, and mooring lines with cetaceans.
Tidal	Interaction of rotating turbine blades with cetaceans, pinnipeds and resident and migratory fishes.
Offshore Wind	Interaction of wind turbine blades with birds and bats.

2.3 STEP 3: IDENTIFY SPATIAL AND TEMPORAL SCALE OF STRESSOR

As described above, Step 2 identifies potential interactions between the stressor and receptor. However, in order to determine the relevance and potential effect of the interactions, it is necessary to determine how often and to what extent each interaction may occur. The first step in this evaluation in Step 3 is to assess the spatial and temporal scales of each individual stressor.

The spatial scales of stressors will be determined by the technology, including the footprint of each device and the footprint of arrays or clusters of devices and their associated infrastructure. Some stressors, like sound, may propagate well beyond the project footprint. The temporal scales of stressors will be determined by the energy technology (either episodic as with offshore wind or wave, or periodic as with tidal), with variability across days, seasons, and years. Stressor effects may also be continuous or intermittent across the duration of the project license. Examples of the kinds of information needed for Step 3 for the three energy sources are shown in Table 2-3.

Table 2-3 Examples of information gathered for Protocols Framework to identify spatial and temporal scale of stressor for a moving (or dynamic) device.

Wave	Spatial scale: Three-dimensional footprint of arrays, including devices, anchors, mooring lines, power cables.

	Temporal scale: While devices are operating.
Tidal	Spatial scale: Three-dimensional footprint of device on seabed and in water column; length of power cable. Temporal scale: During portions of tidal cycle when current exceeds cut-in speed of device.
Offshore Wind	Spatial scale: Three-dimensional footprint of arrays, including rotor and tower, support platform, anchor, mooring lines, power cables. Temporal scale: While devices are operating.

2.4 STEP 4: IDENTIFY EXPOSURE DUE TO OVERLAP OF STRESSORS - RECEPTORS

This step identifies when the biological resources or significant habitat may be at risk due to the presence of the ocean energy devices and associated infrastructure. This is accomplished by evaluating the spatial and temporal attributes of the receptor. Biological species, communities, habitats, and processes also exhibit variable distribution or expression in space and may exhibit both periodic and episodic temporal characteristics. The stressor information is then combined with the receptor information to assess the potential exposure associated with an interaction. The assessment of the exposure may show that a receptor may be especially vulnerable to a stressor at a certain time or space (e.g., an animal life stage that is highly vulnerable to toxic chemicals). Conversely, the assessment may show the receptor to not be particularly vulnerable at a certain time or space (e.g., potential for tidal turbine blade strike for organisms that are in the water column only during slack tides). Understanding the spatial and temporal overlap of the stressors with receptors will further narrow the potential environmental interactions of concern and ultimately focus protocols to measure the most germane aspects of their baseline conditions and effects. Examples of the kinds of information needed for Step 4 for the three energy sources are shown in Table 2-4.

Table 2-4 Example of information gathered for *Protocols Framework* to identify exposure of receptor to stressor.

Wave	*For each population of importance likely to occur in the project area, determine:* Population distribution, age structure, and reproductive rate; seasonal and diel patterns of movement; and Location and operational profile of wave energy devices, anchors, and mooring lines.
Tidal	*For each population of interest likely to occur in the project area, determine:* Population distribution, age structure, and reproductive rate; seasonal and diel patterns of movement; behavior during diving, feeding, resting, and other common activities; and Location and operational profile of tidal devices, including noise of the turbine, which may act as a deterrent to the animals, thus reducing risk of interaction.
Offshore Wind	*For each population of interest likely to occur in the project area, determine:* Population distribution, age structure, and reproductive rate; seasonal and diel patterns of movement; behavior; and Location and operational profile of offshore wind devices, including platforms, anchors, and mooring lines.

2.5 STEP 5: APPLY SCIENTIFIC AND REGULATORY THRESHOLDS

This step in the framework considers the thresholds, from scientific and regulatory point of views, where there is concern that potential injury or mortality of animals and/or alteration of critical habitat could affect marine and/or avian population sustainability or resilience. With completion of Step 4, the user can begin to identify which interactions may occur continuously or routinely or repeatedly and over a significant part of the project area. At this point in the framework process, it is important to identify any existing guidelines or thresholds that may be relevant to a specific stressor–receptor interaction. By defining the scientific and regulatory thresholds, the user of the framework can assess certain levels or duration of the effect of an interaction that may cause the interaction to cross a threshold of concern.

Scientific and regulatory thresholds determine the level of environmental change that may be acceptable due to the development of an ocean energy project. Consequently, those thresholds also define the level of monitoring necessary to resolve the statistical power needed for monitoring data to be used to determine whether environmental effects occur beyond the acceptable scientific or regulatory level. The following example thresholds are applicable for wave, tidal and offshore wind devices:

- **Scientific Thresholds**: Loss of reproductive adults that has an adverse impact on critically small populations.
- **Regulatory Thresholds**: Under the *Endangered Species Act of 1973* (ESA), the taking of listed species through harassment, injury, or mortality is prohibited; incidental take can be permitted if it does not jeopardize the continued existence of the species. Under the *Marine Mammal Protection Act of 1972* (MMPA), the taking of marine mammals through injury or mortality is prohibited, although a permit can be obtained for populations that are not depleted. Under the *Migratory Bird Treaty Act of 1918* (MBTA), the taking of migratory birds through injury or mortality is prohibited.

2.6 STEP 6: IDENTIFY INFORMATION NEEDS TO ESTABLISH BASELINE CONDITIONS

This step in the framework identifies the information needed to understand the condition and trends in populations and habitats prior to installation of ocean energy devices. The framework differentiates between information that is likely to be readily available from surveys undertaken for other purposes and information that may be required for permitting.

Baseline conditions should be known in order to determine the organisms or conditions that exist prior to project deployment if gaps in information exist and to evaluate if changes have occurred to marine receptors due to ocean energy installations. The attributes and natural variability of marine populations, communities, habitats, and ecosystem processes likely to be affected by ocean energy stressors may not be known based on existing information. Baseline information needs should be identified in order to determine the protocols best suited to collect that information.

2.7 STEP 7: IDENTIFY INFORMATION NEEDS TO UNDERSTAND EFFECTS

This step defines the information needed to assess the effect on individuals, populations, and habitats of concern due to the presence and operation of ocean energy devices. The baseline information provides the backdrop for measuring change, and information on effects is needed to demonstrate the specific change to the documented baseline condition that may be caused by project stressors. The information needed to distinguish changes in marine receptors due to ocean energy development will help identify the appropriate protocols to collect that information. In some cases, studies of effects are a continuation of baseline studies. In other situations, information needs for effects and protocols may differ markedly from baseline information needs and protocols. An example of this would be the difference between inferring environmental effects by measuring changes in a population versus direct observation and/or measurement of effects themselves (like collisions). Examples of the kinds of information needed for Step 7 for the three energy sources are shown in Table 2-5.

Table 2-5 Example of information gathered for *Protocols Framework* to identify post-installation effects information needs.

Wave	Studies to evaluate effects of the wave energy device on marine animals, including models of collision and encounter rates, monitoring migration pathways and feeding behavior to detect avoidance/attraction behavior.
Tidal	Studies to evaluate effects of rotating turbine blades on marine animals, including the development of behavioral models of animals in the vicinity of the tidal turbines.
Offshore Wind	Studies to evaluate effects of wind turbines on birds and bats, including models of collision and encounter rates, monitoring flight pathways to detect avoidance/attraction behavior.

2.8 STEP 8: IDENTIFY BASELINE PROTOCOLS

This step in the framework identifies the protocols needed to document the condition of organisms and habitats before the installation of ocean energy devices. The scientific and regulatory thresholds help to determine the resolution that information should be collected. Some protocols may require the data also be collected at reference sites.

For many marine receptors potentially at risk from ocean renewable energy development, there may be existing protocols that can be applied to collect appropriate information; for others, appropriate protocols may be under development or may not exist. Efforts to develop and validate new protocols are necessary for collection of baseline information.

The framework differentiates between protocols that are accepted and in use for surveys undertaken in the marine environment for other purposes and those that still require development and vetting through the scientific and regulatory community. Baseline information needed for projects proposed for each technology include population census, distribution and behavior observations of animals of concern in the project area; and behavior modeling of animals of concern.

2.9 STEP 9: IDENTIFY PROTOCOLS TO EVALUATE POTENTIAL EFFECTS

Step nine identifies the protocols needed to evaluate potential effects of ocean energy devices on individuals, populations, and habitats of concern. The framework differentiates between protocols that are accepted and in use for surveys undertaken in the marine environment for other purposes or used in terrestrial settings as standard protocols, and those that still require development and vetting through the scientific and regulatory community.

Few existing protocols are specific to measuring the direct effects of ocean energy development on marine receptors. However, protocols developed to measure the effects of other activities in the ocean, or those developed on land, can be adopted and modified for post-installation ocean energy monitoring where appropriate. Protocols will need to be developed to collect specific stressor-receptor data that are not readily measured using existing protocols. Examples of the kinds of information needed for Step 9 for the three energy sources are shown in Table 2-6.

Table 2-6 Examples of protocols that could be used for effects monitoring.

Wave	Observations of animals in vicinity of wave energy devices using video and acoustic methods, shore-based and boat-based to determine presence or absence. Tagging of animals in project areas to determine movement and interactions with wave devices, mooring lines and anchors.
Tidal	Observations of animals in vicinity of tidal turbines using video and acoustic methods, including remotely operated vehicles, boat-based and aerial to determine presence or absence. Tagging of animals in project areas to determine movement and behavioral interactions with tidal turbines. Description/measurement of what a tidal turbine blade strike wound or injury would look like on different marine mammal species (as opposed to other injuries).
Offshore Wind	Observations of birds and bats in project area using radar, thermal imagery, acoustic monitoring, boat and aerial surveys to determine presence or absence. Tracking of individual birds using satellite or radio-tracking to determine behavior and flight patterns.

3 PRIORITIES FOR PROTOCOL DEVELOPMENT

Determining the priority stressor–receptor interactions from among the many potential interactions is a significant step in developing the *Protocols Framework*. This chapter describes the process outlined in Step 2 of the *Protocols Framework.* The project team developed the priorities interactions presented here that define the *Protocols Framework* and drive the case studies. Additional information gathered during the process is provided in Appendix B.

3.1 OVERALL APPROACHES TO SETTING PRIORITIES FOR PROTOCOL DEVELOPMENT

The premise for developing protocols through the *Protocols Framework* process requires that data collection be based on the interaction of specific technologies with specific environmental receptors for each renewable ocean energy project. As more information is collected from monitoring renewable ocean energy projects, better predictability of needed studies and methods of data collection will become available.

Three principal sources of knowledge inform the framework's scoping process: expert scientific-based opinion, regulatory requirements, and stakeholder opinion. As described below, and with the supporting information in Appendix B, the project team researched scientific literature, reviewed federal and state statutes, and surveyed stakeholders to develop matrices of interactions between stressors common to ocean renewable energy development and key receptors in the California LME, along the U.S. West Coast.

The full project team, with input from SMEs, evaluated stressor–receptor interactions from three different perspectives: 1) expert opinion (through the PDT and SMEs), 2) regulatory requirements (through the project team), and 3) stakeholder values (through the Stakeholder Advisory Team (SAT) and via a survey to stakeholders and interested public). This approach ensured that each interaction was viewed from different relevant perspectives that are known to have a major influence on the siting, licensing, and permitting process for commercial-scale ocean renewable energy projects.

3.1.1 Choosing Priority Stressor - Receptor Interactions

The team used the four-phase approach described below to identify and evaluate areas of priority:

- **INTERACTION MATRIX DEVELOPED:** The team developed a matrix template (Table 3-1) that identifies and categorizes eight known potential stressors relevant to ocean renewable energy projects and 18 biological and physical receptor groupings that may be affected by these stressors. This matrix resulted in 144 row-column intersections (stressor–receptor interactions). Environmental stressors and receptors are defined in Tables 3-2 and 3-3.
- **MATRIX POPULATED FROM EACH PERSPECTIVE:** One matrix was completed from each perspective, (expert scientific opinion, regulatory, and stakeholder values) and for each type of ocean renewable energy technology (wave,

tidal, and offshore wind). Criteria for high-medium-low-no impact were developed from each perspective and are summarized in Sections 3.2.1, 3.2.2, and 3.2.3. For each stressor–receptor interaction in the matrix, the priority for monitoring was determined. The approach for rating the priorities differed among perspectives, as discussed below.

- **INTEGRATED ANALYSIS:** For each type of ocean renewable energy technology (wave, tidal, and offshore wind), the expert scientific opinion, regulatory, and stakeholder values evaluations are combined in an integrated analysis. Criteria, described in Section 3.3, were developed to determine monitoring priorities. Based on these criteria, the monitoring priorities are summarized into a single list for each technology and are presented in Sections 3.3.1, 3.3.2, and 3.3.3.
- **CHOOSING PRIORITY INTERACTIONS FOR FRAMEWORK APPLICATION:** The PDT evaluated all stressor–receptor interactions to select priority interactions that would provide the most meaningful test and evaluation of the protocols framework. The criteria used for this selection and the resulting 14 priority stressor–receptor interactions are presented in Section 3.4.

Table 3-1 The template matrix developed for the identification ocean renewable energy priorities for protocol development, with environmental stressors as rows A–H, and environmental receptor groupings as columns 1–18.

	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	1	11	12	13	14	15	16	17	18
A	**Static devices**																		
B	**Moving devices**																		
C	**Energy removal**																		
D	**Chemical release**																		
E	**Noise and vibration**																		
F	**EMF**																		
G	**Boat traffic**																		
H	**Lights**																		

Table 3-2 Stressor definitions used in the environmental stressor–receptor interaction matrices.

Stressor	**Definition**
A. Static Devices	The presence of device components (surface or subsurface) and subsurface support structures/mooring systems, including lines and anchors.
B. Moving Devices	The interaction of receptors with the movement of devices above the water surface, at the water surface, or completely submerged, not the energy extraction that results from moving parts. Greater impacts to plankton, pelagic invertebrates, and small fishes could occur if the device includes pumping or overtopping mechanisms that may cause entrainment.
C. Energy Removal	The energy in the oceanic system that is converted by the device and thus ‘removed’ from the ocean. It is an area of high variability and uncertainty, depending on the type of device. The impact of this stressor will depend on the amount of energy removed by the installation.
D. Chemical Releases	Limited to minor releases of oils or hydraulic fluids and chemical release from anti-fouling paints, not major catastrophic spills.
E. Noise and Vibration	Include loud short-term construction noise and lower-amplitude long-term noise from operational devices and mooring systems during operation.
F. EMF	The electromagnetic fields associated with the energy-generating device and/or the subsea cables that carry the electricity to shore. The magnitude of these fields is uncertain, as is the response of organisms to those fields.
G. Lighting	Includes navigation lights on offshore wind turbines, at or near the top of wave energy converters, near the water’s surface (e.g., on navigation buoys) to mark completely submerged devices, lights on boats (used in navigation, and construction and maintenance), and construction lighting.
H. Boat Traffic	Will be frequent at the initiation of a project during the installation phase. Traffic will be periodic during the operations phase of a project as used for regular maintenance.

Table 3-3 Receptor definitions used in the environmental stressor–receptor interaction matrices.

Receptor	Definition
1. Sediment Characteristics	Include changes in grain size and sediment transport that may result in changes to nearfield or farfield sedimentation patterns.
2. Water Circulation	Changes in flow regime or stratification.
3. Water Chemistry	Changes in temperature, salinity, dissolved oxygen, and other chemical components due to changes in circulation.
4. Nearfield Habitat	Changes to habitat (benthic and pelagic) within and local to the array (within 10 m in all directions).
5. Farfield Habitat	Changes to the habitat (benthic and pelagic) farther than 10 m from the array. This may include downstream or shoreline changes.
6. Ecosystem Interactions	Include the fish attraction device (FAD) effect or artificial reef effect, including invertebrates settling on or colonizing underwater structures, and the potential attraction of predator fish, sharks, and birds to increased prey availability. This receptor encompasses changes to the marine food web and other cumulative interactions in the ecosystem.
7. Benthic Invertebrates	Consists of organisms living on or within the seabed, including important macroinvertebrates such as crabs.
8. Nektonic Invertebrates	Consists of invertebrates that live in the water column, mainly squid. Micronekton includes euphausiids and mysids, as well as gelatinous organisms.
9. Plankton	Includes phytoplankton, invertebrate zooplankton, and larval fishes.
10. Resident Fishes	Fishes with limited home ranges. These may be sand- or reef-associated, most commonly rockfish on the U.S. West Coast.
11. Migratory Fishes	Fish that migrate in coastal ocean waters along the U.S. West Coast. The greatest focus is on salmonids and green sturgeon.
12. Elasmobranchs	Includes sharks, skates, and rays.
13. Sea Turtles	Include all six species that migrate and feed in U.S. waters, although leatherback sea turtles are the only species known to migrate along the U.S. West Coast.
14. Cetaceans	Include resident and migratory whales, porpoises, and dolphins.
15. Pinnipeds	Include seals and sea lions.
16. Mustelids	Include sea otters that occur in coastal waters; river otters may also occur nearshore.
17. Bats	Some bats fly offshore (e.g., during migration) and may interact with ocean energy devices on the surface, depending on distance from shore.
18. Birds	Any type of migratory or resident birds (e.g., seabirds, shorebirds, passerines, raptors, waterfowl) that may interact with surface or sub-surface components of the devices.

3.2 PRIORITIES FROM DIFFERENT PERSPECTIVES

The project team defined priorities for expert scientific opinion, regulatory requirements, and stakeholder values using the process described in the following sections.

3.2.1 Expert Scientific Opinion

The PDT used existing information to establish priorities for monitoring for each technology (wave, tidal, offshore wind) and populated the stressor–receptor interaction matrix accordingly. The matrices for each technology were then reviewed by the other PDT members and by the full project team. SMEs with expertise in the stressors or receptors were selected to review this work.

In the absence of a substantial number of scientific studies on stressor-receptor interactions of ocean energy devices, the PDT relied on the judgment of marine scientists and practitioners (SMEs), with an emphasis on professionals working to develop the understanding of environmental effects of these new ocean energy industries. The SME's and PDT drew largely from the literature that offers insights into interactions of industrial development in the ocean, and from synthesis and workshop reports that have been assembled to address ocean energy effects. The offshore wind literature is somewhat more robust than that for wave and tidal development, drawing from work in Europe, however many of the studies require considerable interpretation to understand their applicability to North American waters, animal populations and habitats. Recent syntheses that helped direct the expert scientific opinion in this framework include reports from workshops on the environmental effects of wave and tidal energy development, held in Newport OR in 2007 (Boehlert et al, 2008) and Seattle WA (Polagye et al, 2011) in 2010, respectively.

The stressor-receptor rankings for effects and impacts are an amalgam of information gleaned from the published literature and the best professional judgment of a group of over 30 marine scientists and practitioners in ocean energy device interactions. The SMEs and their areas of expertise are listed in the Acknowledgements section at the beginning of this report. (See glossary for a robust definition of professional judgment.)

Ranking the magnitude of potential effect applied to each stressor–receptor interaction:

High Priority for Monitoring and Protocol Development *[red cells]* is defined as interactions that meet either one or both tests:

a) Have a potentially **significant and measurable impact** on the receptor (population-level for biological receptors or individual-level in the case of very small populations), the duration of the impact is long term (i.e., relative to the life history of the organisms or the life of the project), and is expected to have a significant spatial and/or temporal overlap (i.e., exposure) with the receptor.; and/or

b) Have **great uncertainty** relating to the level of exposure or the magnitude of effect.

Medium Priority for Monitoring and Protocol Development *[orange cells]* is defined as interactions that meet one or both tests:

a) Have a potentially **measurable impact** on the receptor (population level for biological receptors or individual level in the case of very small populations). An impact is described as medium either because the duration is expected to be short-term rather than long-term (i.e., boat traffic and chemical releases that are occasional and not constant) or because it does not have a significant spatial and/or temporal overlap with the receptor (i.e., the receptor is migratory); and/or

b) Have **uncertainty** relating to the level of exposure or the magnitude of an effect.

Low Priority for Monitoring and Protocol Development *[green cells]* is defined as potentially having **some effect** on individuals (e.g., behavior change), but the magnitude of the effect is considered to be small. An interaction may result in an effect but not an impact because the duration is short term and/or does not have a significant spatial and/or temporal overlap with the receptor.

No interaction is defined as lacking a known mechanism or opportunity for the stressor to act on the receptor.

3.2.2 Regulatory Stringency

A subteam of the project team evaluated federal and state environmental regulations applicable to renewable ocean energy technologies[1]. Using this information, the subteam completed a stressor–receptor matrix that identified monitoring priorities for each type of ocean renewable energy project (wave, tidal and offshore wind). The priority determination was based on the level of regulatory stringency that may be applied to an interaction. For instance, a regulation that has strict prohibitions on take of a species would be indicated as high priority for monitoring. The regulatory review did not consider or evaluate any interactions determined by the expert opinion matrix to have "no interaction."

Definition of the magnitude of potential effect applied to each stressor–receptor interaction:

High Priority for Monitoring and Protocol Development *[red cells]* represent those interactions that are under the authority of regulations that include strict take prohibitions and/or regulatory requirements. Examples include the *Endangered Species Act*, *Marine Mammal Protection Act*, and/or the *Migratory Bird Treaty Act*.

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[1] This process looked specifically at environmental regulations that may be applied to ocean renewable energy development. This process did not consider in detail the requirements of any overarching federal or state leasing or licensing processes but focused on the environmental regulations that would be considered as part of those processes.

Medium Priority for Monitoring and Protocol Development [*orange cells*] represent those interactions that are under the authority of regulations that include moderate take prohibitions and/or regulatory requirements. Examples include federal and state *Clean Water Act*, state listed species, and/or state/tribal protected resources.

Low Priority for Monitoring and Protocol Development [*green cells*] represent those interactions that are subject to regulatory authorities, however, the implementation of authority may not be prescriptive or is not expected to be significant. Examples include the *Magnuson–Stevens Fisheries Conservation and Management Act*.

No Interaction [*white cells]* is defined as lacking a known mechanism or opportunity for the stressor to act on the receptor.

Regulatory thresholds are addressed in more detail in Appendix C on Environmental Thresholds and Criteria.

3.2.3 Stakeholder Values

The project team used project regulatory filings and direct knowledge from existing projects on the West Coast to develop an initial list of stressor–receptor issues that stakeholders have previously identified as being potentially important or highly important for further evaluation. The initial list of interactions was developed consistent with, but not in the exact form of, the stressor–receptor interaction matrix. Some interactions were simplified to effectively communicate stakeholder interests. This issues list was reviewed, discussed, and then modified by the SAT.

To evaluate the list of interactions in a way that represented broad stakeholder input, an on-line survey was developed that asked respondents to rate the stressor–receptor interactions identified above. The survey was designed to assess which stressor–receptor interactions stakeholders viewed as important. Stakeholders could rate the interactions as *highly important*, *important*, *not important* (see definitions presented within the following boxes) or indicate that they *didn't know/needed more information*.

To keep the survey manageable in content and time, it did not ask for feedback on all the potential stressor–receptor interactions defined in the matrix. To capture an interaction that someone might feel was important but was not on the list, respondents could list those specifically in a comment box. A copy of the survey and the summary of responses are included in Appendix B.

<u>Definition of the magnitude of potential effect applied to each stressor–receptor interaction:</u>

Highly Priority for Monitoring and Protocol Development [*red cells*] represents the potential effects that could cause serious damage to a biological population/community and/or those that could have significant and possibly irreversible environmental effects.

Medium Priority for Monitoring and Protocol Development *[orange cells]* represents the potential effects that could have a measurable impact and could be assessed through environmental monitoring.
Low Priority for Monitoring and Protocol Development *[green cells]* represents the potential effects will not have a measurable impact due to low probability of exposure or small impact from interaction.

For purposes of the summary matrix, an additional category was developed to indicate those interactions that were not included in the stakeholder survey, shown as gray shading.

- **N/A Not Reviewed *[gray cells]*** - Represents interactions for which a question was not included in the stakeholder survey.

3.3 PRIORITIES FOR MONITORING AND PROTOCOL DEVELOPMENT

The stressor–receptor matrices for wave, tidal and offshore wind technologies are presented in the sections below. Each table incorporates all three perspectives and is arranged by energy technology. Individual matrices for each perspective are included in Appendix B.

A list of priorities for monitoring and protocol development was developed for each of the three technologies based on a review of the combined expert opinion, regulatory, and stakeholder values matrices.

The project team developed criteria to incorporate all three perspectives to create a single list of priorities for protocol development for each ocean energy technology. The criteria for selecting the high or medium priority stressor–receptor interactions for monitoring and effects protocol development were applied as follows:

a. Any interaction including one or more red designation from any perspective, or
b. Any interaction including two or more orange designations from any perspective, or
c. Any interaction including an orange from the expert opinion perspective.

Some interactions were indicated as of high importance by stakeholders only and were not indicated as high or medium priority from the expert opinion or regulatory perspectives. These interactions were reviewed by the PDT and deemed of medium priority (e.g., chemical release and sediment characteristics for all technologies; migratory fish and static devices for tidal technologies).

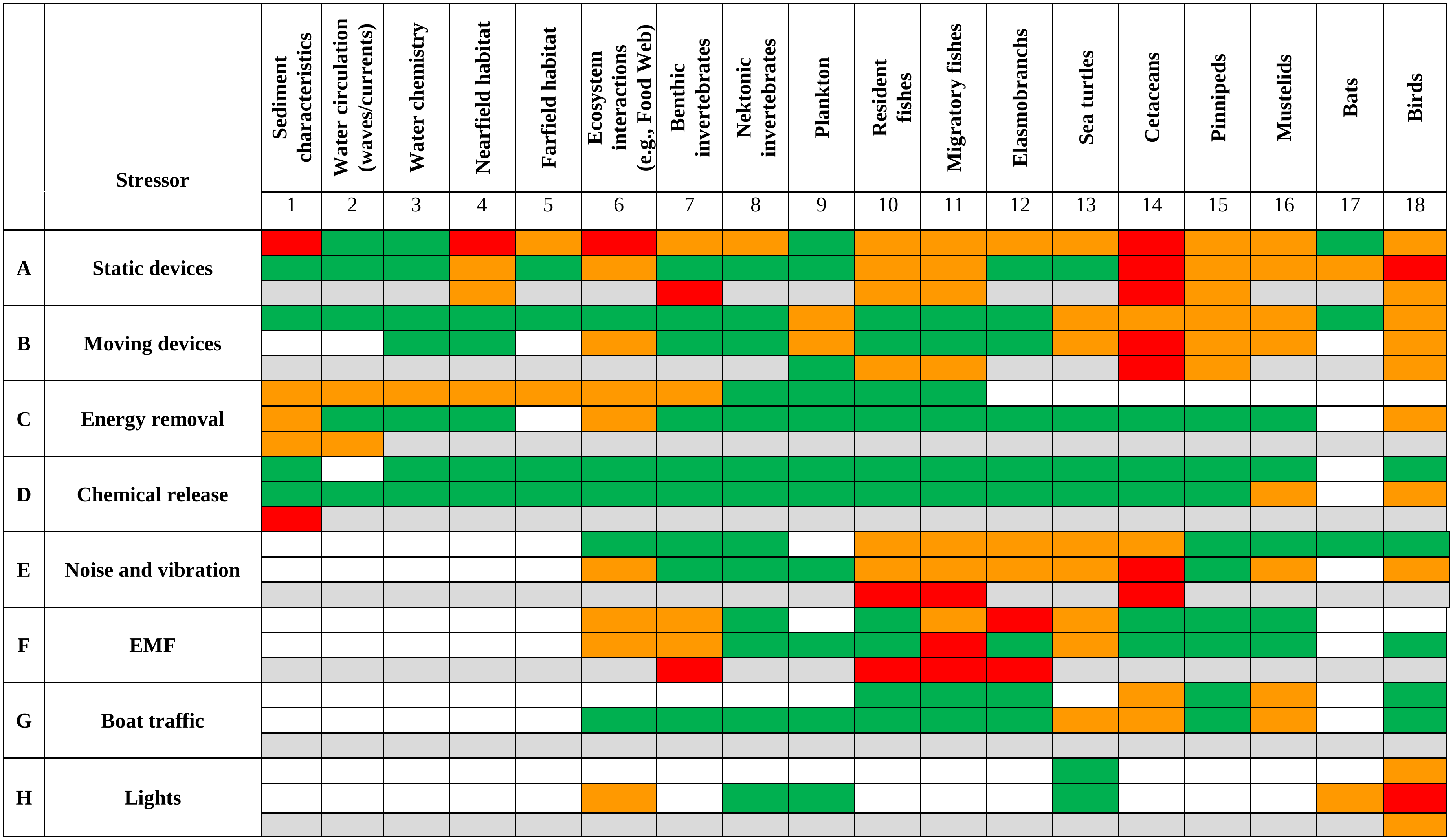
The integrated wave, tidal, and offshore wind matrices displaying the opinions from all three perspectives are presented in Tables 3-4, 3-6, and 3-8. Of the 144 possible stressor–receptor interactions, those that scored medium or high totaled 42 for wave energy, 29 for tidal energy, and 32 for offshore wind energy. These priority interactions are shown in Tables 3-5, 3-7, and 3-9. A complete list of these priority interactions is also provided below each set of tables. Apparent differences in the level of importance assigned to a stressor-receptor interaction among ocean energy technologies is largely due to the specific interactions that can be expected due to differences in the configuration of the device, the mooring and foundation structure, and operational characteristics of the specific energy harvest mechanism. For example, wave devices maybe expected to cause disruption to nearfield habitats as their moorings may create hard-bottom habitat from previous soft-bottom, affecting benthic communities and marine food webs. Tidal devices are deployed in faster moving bottom waters where benthic communities and soft-bottom habitats tend to be scarce. This dichotomy may lead to increased emphasis on potential impacts on bottom habitats and benthic organisms for wave devices over tidal devices. Similarly, rotating tidal blades present greater hazards for marine animals coming into contact with the device than wave buoys, creating an emphasis on the dynamic presence of the tidal device. The baseline and effects information needed to determine the specific interactions of stressors-receptors for each technology type may differ, depending on the potential importance of the effects. The priorities set for further investigation as part of this framework reflect these differences.

3.3.1 Wave Energy

Table 3-4 presents the wave energy results for expert opinion, regulatory stringency, and stakeholder opinion. The stressor–receptor interactions that scored medium or high are shown in Table 3-5 and are listed and described in the context of wave energy development. The color key for Tables 3-4 and 3-5 is shown below:

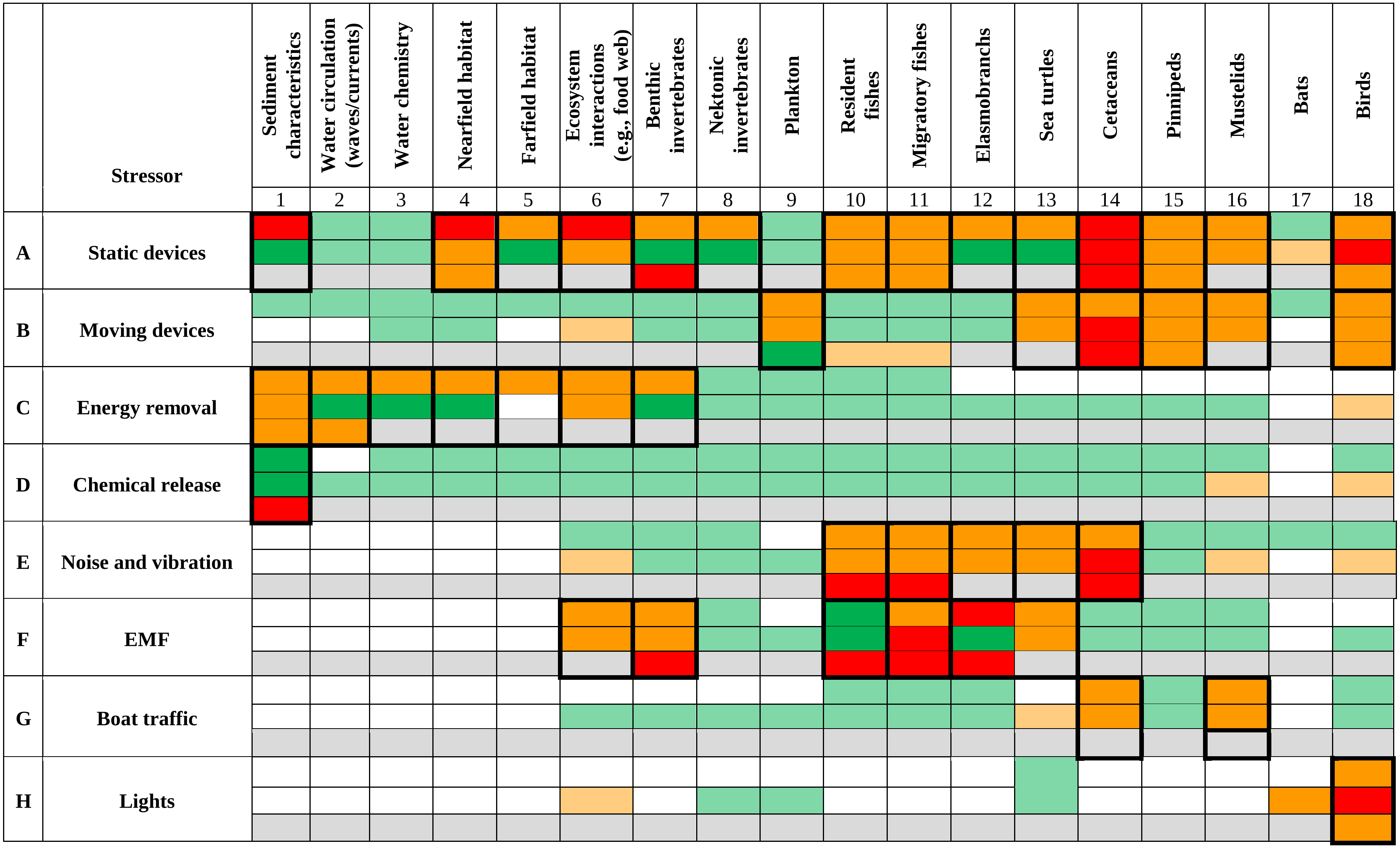
🟥 **= High Priority**
🟧 **= Medium Priority**
🟩 **= Low Priority**
⬜ **= No Interaction**
▒ **= N/A Not Reviewed**

Table 3-4 Expert opinion, regulatory stringency, and stakeholder values for wave energy: perspectives from expert opinion (top), regulatory protections in place (middle), and stakeholder values (bottom) on the potential importance of generic receptors as a result of generic stressors from wave energy projects.



	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions (e.g., Food Web)	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟥	🟩	🟩	🟥	🟧	🟥	🟧	🟧	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟧	🟩	🟧
		🟩	🟩	🟩	🟧	🟩	🟧	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟥	🟧	🟧	🟧	🟥
		▨	▨	▨	🟧	▨	▨	🟥	▨	▨	🟧	🟧	▨	▨	🟥	🟧	▨	▨	🟧
B	**Moving devices**	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟩	🟧
				🟩	🟩		🟧	🟩	🟩	🟧	🟩	🟩	🟩	🟧	🟥	🟧	🟧		🟧
		▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟧	🟧	▨	▨	🟥	🟧	▨	▨	🟧
C	**Energy removal**	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩							
		🟧	🟩	🟩	🟩		🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟧
		🟧	🟧	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
D	**Chemical release**	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧		🟧
		🟥	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
E	**Noise and vibration**						🟩	🟩	🟩		🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩
							🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟩	🟧		🟧
		▨	▨	▨	▨	▨	▨	▨	▨	▨	🟥	🟥	▨	▨	🟥	▨	▨	▨	▨
F	**EMF**						🟧	🟧	🟩		🟩	🟧	🟥	🟧	🟩	🟩	🟩		
							🟧	🟧	🟩	🟩	🟩	🟥	🟩	🟧	🟩	🟩	🟩		🟩
		▨	▨	▨	▨	▨	▨	🟥	▨	▨	🟥	🟥	🟥	▨	▨	▨	▨	▨	▨
G	**Boat traffic**										🟩	🟩	🟩		🟧	🟩	🟧		🟩
							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧		🟩
		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
H	**Lights**													🟩					🟧
							🟧		🟩	🟩				🟩				🟧	🟥
		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟧

Table 3-5 Priorities for protocol development for generic wave energy development. The priorities are summed from 1) expert opinion (top), 2) regulatory protections in place (middle), and 3) stakeholder values (bottom). Black borders indicate priority issues.



	Stressor	Sediment characteristics 1	Water circulation (waves/currents) 2	Water chemistry 3	Nearfield habitat 4	Farfield habitat 5	Ecosystem interactions (e.g., food web) 6	Benthic invertebrates 7	Nektonic invertebrates 8	Plankton 9	Resident fishes 10	Migratory fishes 11	Elasmobranchs 12	Sea turtles 13	Cetaceans 14	Pinnipeds 15	Mustelids 16	Bats 17	Birds 18
A	Static devices	🟥	🟢	🟢	🟥	🟧	🟥	🟧	🟧	🟢	🟧	🟧	🟧	🟧	🟥	🟧	🟧	🟢	🟧
		🟩	🟢	🟢	🟧	🟩	🟧	🟩	🟩	🟢	🟧	🟧	🟩	🟩	🟥	🟧	🟧	🟨	🟥
					🟧			🟥			🟧	🟧			🟥	🟧			🟧
B	Moving devices	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟧	🟢	🟢	🟢	🟧	🟧	🟧	🟧	🟢	🟧
				🟢	🟢		🟨	🟢	🟢	🟧	🟢	🟢	🟢	🟧	🟥	🟧	🟧		🟧
										🟩	🟨	🟨			🟥	🟧			🟧
C	Energy removal	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟢	🟢	🟢	🟢							
		🟧	🟩	🟩	🟩		🟧	🟩	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢		🟨
		🟧	🟧																
D	Chemical release	🟩		🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢		🟢
		🟩	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟨		🟨
		🟥																	
E	Noise and vibration						🟢	🟢	🟢		🟧	🟧	🟧	🟧	🟧	🟢	🟢	🟢	🟢
							🟨	🟢	🟢	🟢	🟧	🟧	🟧	🟧	🟥	🟢	🟨		🟨
											🟥	🟥			🟥				
F	EMF						🟧	🟧	🟢		🟩	🟧	🟥	🟧	🟢	🟢	🟢		
							🟧	🟧	🟢	🟢	🟩	🟥	🟩	🟧	🟢	🟢	🟢		🟢
								🟥			🟥	🟥	🟥						
G	Boat traffic										🟢	🟢	🟢		🟧	🟢	🟧		🟢
							🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟨	🟧	🟢	🟧		🟢
H	Lights													🟢					🟧
							🟨		🟢	🟢				🟢				🟧	🟥
																			🟧

Wave Energy - High Priority/High Importance

- *Static devices and nearfield habitat.* This interaction includes changes to sediment characteristics and water circulation (as the driver of changes to sediment characteristics). These are the major mechanisms by which the nearfield habitat may be changed. Anchors will change a proportion of the benthic habitat from sediment to hard bottom. In addition, scour around the anchoring systems may alter the distribution of sediment grain sizes in the vicinity.
- *Static devices and ecosystem interactions.* This interaction is based on the change to the nearfield habitat that may change the organisms using that habitat and, thus, their interactions with one another. Hard structures may serve as fish attractors, attracting a different assemblage than would have been found over sediment. Changes to grain size will affect infaunal organism distributions and therefore fish presence.
- *Static/moving devices and cetaceans.* Cetaceans could collide with underwater static or moving devices or become entangled in mooring lines. Furthermore, behavioral changes associated with avoiding static or moving devices may result in different energetic requirements, feeding opportunities, or access to habitats for other life history requirements; for example, breeding.
- *EMF and elasmobranchs.* Changes to electromagnetic fields may affect elasmobranchs behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey (Gill 2005) and deny access to habitats required for other life history requirements (e.g., breeding).

Wave Energy - Medium Priority/Important

- *EMF and Fishes and Invertebrates.* Changes to electric and/or magnetic fields may affect navigation abilities of migratory fishes, particularly green sturgeon, some species of salmon, sea turtles, and also the behavior of Dungeness crabs. These effects and potential impacts to feeding behavior of elasmobranchs may result in changes at the level of the ecosystem (i.e., ecosystem interactions, per se).
- *Static devices and benthic invertebrates.* Bottom-mounted device components can change local sediment characteristics, with potential effects on benthic invertebrates whose distributions are tied to sediment type, particularly grain size.
- *Energy and nearfield/farfield habitat.* Energy removal from commercial-scale projects has the potential to impact sediment movement, erosion, and sanding-in of hard bottom in the farfield. Until we have better results from modeling of commercial scale projects, this is not elevated to the level of a high priority effect, but it has potential.
- *Static devices and sea turtles, pinnipeds, mustelids, and birds.* Devices and associated mooring lines provide opportunity for collision and entanglement for sea

turtles, pinnipeds, mustelids, and birds. Similarly, behavioral changes associated with avoiding installations may result in different energetic requirements, feeding opportunities, or access to habitats for other purposes.

- *<u>Static devices and nektonic invertebrates, plankton, resident fishes, and migratory fishes</u>*. The addition of hard substrate (static devices) may result in attraction of benthic invertebrates, nektonic invertebrates, plankton, resident fishes, and migratory fishes to the project area.
- *<u>Chemical release and nearfield habitat</u>*. The accidental release of toxic chemicals from operational or servicing accidents may have impacts, especially at habitat interfaces (i.e., air-water or water-substrate).
- *<u>Noise/vibration and fishes, elasmobranchs sea turtles, and cetaceans</u>*. Noise and vibration effects on fishes, elasmobranchs, sea turtles and cetaceans are expected to have a moderate likelihood of impact.
-

3.3.2 Tidal Energy

Table 3-6 presents the tidal energy results for expert opinion, regulatory stringency, and stakeholder opinion. The stressor–receptor interactions that scored medium or high are shown in Table 3-7 and are listed and described in the context of tidal energy development. The color key for Tables 3-6 and 3-7 is shown below:

🟥 **= High Priority** 🟧 **= Medium Priority** 🟩 **= Low Priority** ⬜ **= No Interaction** ▒ **= N/A Not Reviewed**

Table 3-6 Expert opinion, regulatory stringency and stakeholder values for tidal energy. Perspectives from expert opinion (top), regulatory protections in place (middle), and stakeholder values (bottom) on the potential importance of generic receptors as a result of generic stressors from tidal energy projects.

	Stressor	**Sediment characteristics**	**Water circulation (waves/currents)**	**Water chemistry**	**Nearfield habitat**	**Farfield habitat**	**Ecosystem interactions (e.g., food web)**	**Benthic invertebrates**	**Nektonic invertebrates**	**Plankton**	**Resident fishes**	**Migratory fishes**	**Elasmobranchs**	**Sea turtles**	**Cetaceans**	**Pinnipeds**	**Mustelids**	**Bats**	**Birds**
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟧	🟧	🟧	🟧	🟩	🟩	🟧	🟩	🟩	🟧	🟩	🟩		🟩	🟩			🟩
		🟩	🟩	🟩	🟧	🟩	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟧	🟧		🟩
					🟧						🟥	🟥			🟥				🟧
B	**Moving devices**						🟧	🟩	🟩	🟩	🟧	🟧	🟧		🟥	🟥			🟩
				🟩	🟩		🟧	🟩	🟩	🟩	🟧	🟧	🟩	🟧	🟥	🟥	🟧		🟧
											🟥	🟥			🟥				🟧
C	**Energy removal**	🟧	🟧	🟧	🟩	🟩	🟧												
		🟧	🟩	🟥	🟩		🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
		🟥	🟥																
D	**Chemical release**			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩	🟩			🟩
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧		🟧
		🟥					🟧												
E	**Noise and vibration**							🟩	🟩		🟩	🟩	🟩		🟥	🟧			🟧
							🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟧		🟧
											🟥	🟥			🟥				
F	**EMF**							🟧	🟩		🟧	🟧	🟥		🟩	🟩			
							🟧	🟩	🟩	🟩	🟩	🟥	🟩	🟧	🟩	🟩	🟩		🟩
											🟧	🟧	🟧						
G	**Boat traffic**										🟩	🟩	🟩		🟩	🟩			🟩
							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧		🟩
H	**Lights**																		
							🟧												

Table 3-7 Priorities for protocol development for generic tidal energy development. Priorities are summed from 1) expert opinion (top), 2) regulatory protections in place (middle), and 3) stakeholder values (bottom). Black borders indicate priority issues.

	Stressor	Sediment characteristics 1	Water circulation (waves/currents) 2	Water chemistry 3	Nearfield habitat 4	Farfield habitat 5	Ecosystem interactions (e.g., food web) 6	Benthic invertebrates 7	Nektonic invertebrates 8	Plankton 9	Resident fishes 10	Migratory fishes 11	Elasmobranchs 12	Sea turtles 13	Cetaceans 14	Pinnipeds 15	Mustelids 16	Bats 17	Birds 18
A	**Static devices**	🟧	🟧	🟧	🟧	🟢	🟢	🟧	🟢	🟢	🟧	🟩	🟢		🟩	🟢			🟢
		🟩	🟩	🟩	🟧	🟢	🟨	🟩	🟢	🟢	🟩	🟩	🟢	🟢	🟥	🟨	🟨		🟢
		▨	▨	▨	🟧	▨	▨	▨	▨	▨	🟥	🟥	▨	▨	🟥	▨	▨	▨	🟨
B	**Moving devices**						🟧	🟢	🟢	🟢	🟧	🟧	🟧		🟥	🟥			🟩
				🟢	🟢		🟧	🟢	🟢	🟢	🟧	🟧	🟩	🟨	🟥	🟥	🟨		🟧
		▨	▨	▨	▨	▨	▨	▨	▨	▨	🟥	🟥	▨	▨	🟥	▨	▨	▨	🟧
C	**Energy removal**	🟧	🟧	🟧	🟢	🟢	🟧												
		🟧	🟩	🟥	🟢		🟧	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢		
		🟥	🟥	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
D	**Chemical release**			🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢		🟢	🟢			🟢
		🟩	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟨		🟨
		🟥	▨	▨	▨	▨	🟨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
E	**Noise and vibration**							🟢	🟢		🟩	🟩	🟢		🟥	🟧			🟧
							🟨	🟢	🟢	🟢	🟧	🟧	🟨	🟨	🟥	🟧	🟨		🟧
		▨	▨	▨	▨	▨	▨	▨	▨	▨	🟥	🟥	▨	▨	🟥	▨	▨	▨	▨
F	**EMF**							🟧	🟢		🟧	🟧	🟥		🟢	🟢			
							🟨	🟩	🟢	🟢	🟩	🟥	🟩	🟨	🟢	🟢	🟢		🟢
		▨	▨	▨	▨	▨	▨	▨	▨	▨	🟧	🟧	🟧	▨	▨	▨	▨	▨	▨
G	**Boat traffic**										🟢	🟢	🟢		🟢	🟢			🟢
							🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟨	🟨	🟢	🟨		🟢
		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
H	**Lights**																		
							🟨												
		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Tidal Energy - High Priority/Highly Important

- *Moving devices and cetaceans and pinnipeds*. Cetaceans and pinnipeds may potentially swim into rotating blades, by accident or out of curiosity.
- *Noise/vibration and cetaceans*. Acoustic output from rotating blades may disrupt cetacean communication and navigation, denying access to important habitats for feeding/breeding.
- *EMF and elasmobranchs*. Changes to electromagnetic fields may affect elasmobranchs behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey.

Tidal Energy - Medium Priority/Important

- *Static devices and sediment characteristics*. Reductions of tidal flow due to presence of tidal turbines on seabed may cause changes in sedimentation patterns farfield, affecting benthic habitat and perhaps nearshore habitat.
- *Static devices and water chemistry*. Reductions of flow may cause changes in farfield circulation and chemical flux, resulting in increased areas of low dissolved oxygen concentrations and perhaps changes in nutrient concentrations.
- *Static devices and nearfield habitat*. Changes in nearfield habitat due to foundation of tidal turbine.
- *Static devices and benthic invertebrates*. The presence of devices on the seabed could interrupt use of soft-bottom benthic habitat for crustaceans and other macrofauna.
- *Static devices and fishes*. The presence of devices on the seabed will likely act as an attractant for reef fish, potentially putting them in harm's way when the turbine blades rotate.
- *Moving devices and ecosystem interactions*. Changes in flow in the tidal basin could cause changes in macro and micro nutrient availability, changing phytoplankton growth and the marine food web.
- *Moving devices and fishes*. Rotating turbine blades could present risk to resident fish, migratory fish, and/or sharks from strike (adults), entrainment, or impingement (eggs, larvae, juveniles). High degree of uncertainty.
- *Energy removal and sediment characteristics and water chemistry*. Changes in circulation due to energy removal could cause changes in water chemistry and farfield changes in sediment patterns in low-energy areas and nearshore.
- *Energy removal and ecosystem interactions*. Removal of energy and change in flow in tidal basins could cause ”bottom-up” trophic impacts through changes in phytoplankton growth dynamics and the marine or estuarine food web.

- *Noise/vibration and pinnipeds*. Noise output from rotating turbine blades may affect pinnipeds, but no definitive data exist to predict effects or impacts.
- *Noise/vibration and birds*. Noise and vibration during installation could be a problem for birds. Diving birds could be disturbed by operational noise output from turbine.
- *EMF and benthic invertebrates*. Potential effects of EMF on crustaceans like Dungeness crab, decreasing efficiency in seeking prey and avoiding predators (supporting data for Dungeness crab are anecdotal, see Boehlert et al. 2008).
- *EMF and fishes*. Potential effects of EMF on migratory fish, affecting migratory behavior and also perhaps reducing ability to evade prey or causing developmental delays. This impact was also ranked as important because it has a relatively high level of uncertainty.

3.3.3 Offshore Wind Energy

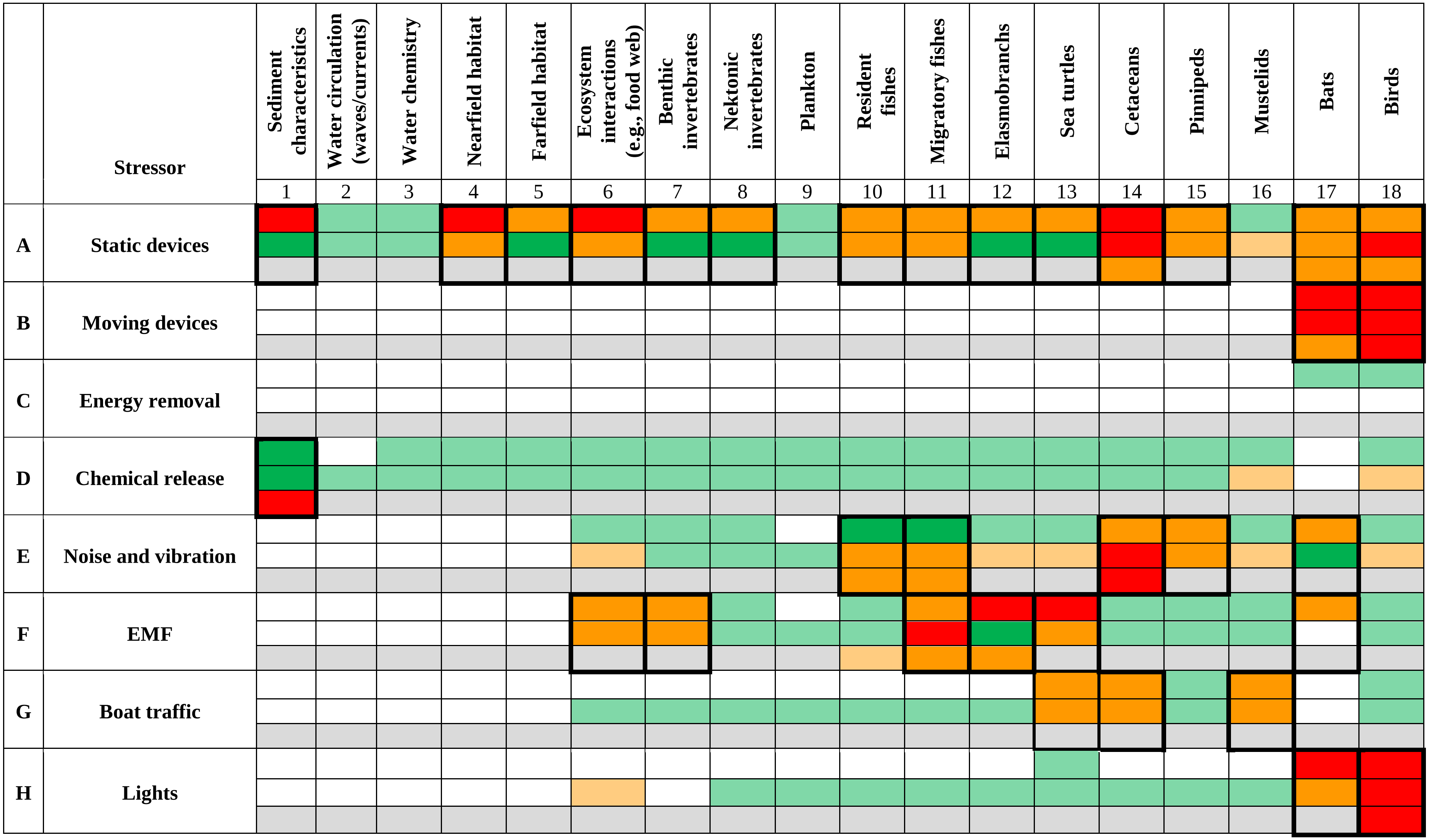
Table 3-8 presents the offshore wind energy results for expert opinion, regulatory stringency, and stakeholder opinion. The stressor–receptor interactions that scored medium or high are shown in Table 3-9 and are listed and described in the context of offshore wind energy development. The color key for Tables 3-8 and 3-9 are shown below:

🟥 **= High Priority**
🟧 **= Medium Priority**
🟩 **= Low Priority**
⬜ **= No Interaction**
▩ **= N/A Not Reviewed**

Table 3-8 Expert opinion, regulatory stringency, and stakeholder values for offshore wind energy**.** Perspectives from expert opinion (top), regulatory protections in place (middle), and stakeholder values (bottom) on the potential importance of generic receptors as a result of generic stressors from offshore wind energy projects.

	Stressor	**Sediment characteristics**	**Water circulation (waves/currents)**	**Water chemistry**	**Nearfield habitat**	**Farfield habitat**	**Ecosystem interactions (e.g,' food web)**	**Benthic invertebrates**	**Nektonic invertebrates**	**Plankton**	**Resident fishes**	**Migratory fishes**	**Elasmobranchs**	**Sea turtles**	**Cetaceans**	**Pinnipeds**	**Mustelids**	**Bats**	**Birds**
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟥	🟩	🟩	🟥	🟧	🟥	🟧	🟧	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟩	🟧	🟧
		🟩	🟩	🟩	🟧	🟩	🟧	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟥	🟧	🟧	🟧	🟥
															🟧			🟧	🟧
B	**Moving devices**																	🟥	🟥
																		🟥	🟥
																		🟧	🟥
C	**Energy removal**																	🟩	🟩
D	**Chemical release**	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧		🟧
		🟥																	
E	**Noise and vibration**						🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧	🟩
							🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟧	🟩	🟧
											🟧	🟧			🟥				
F	**EMF**						🟧	🟧	🟩		🟩	🟧	🟥	🟥	🟩	🟩	🟩	🟧	🟩
							🟧	🟧	🟩	🟩	🟩	🟥	🟩	🟧	🟩	🟩	🟩		🟩
											🟧	🟧	🟧						
G	**Boat traffic**													🟧	🟧	🟩	🟧		🟩
							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧		🟩
H	**Lights**													🟩				🟥	🟥
							🟧		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟥
																			🟥

Table 3-9 Priorities for protocol development for generic offshore wind energy development. Priorities are summed from 1) expert opinion (top), 2) regulatory protections in place (middle), and 3) stakeholder values (bottom). Black borders indicate priority issues.



	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions (e.g., food web)	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟥	🟢	🟢	🟥	🟧	🟥	🟧	🟧	🟢	🟧	🟧	🟧	🟧	🟥	🟧	🟢	🟧	🟧
		🟩	🟢	🟢	🟧	🟩	🟧	🟩	🟩	🟢	🟧	🟧	🟩	🟩	🟥	🟧	🟡	🟧	🟥
															🟧			🟧	🟧
B	**Moving devices**																	🟥	🟥
																		🟥	🟥
																		🟧	🟥
C	**Energy removal**																	🟢	🟢
D	**Chemical release**	🟩		🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢		🟢
		🟩	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟡		🟡
		🟥																	
E	**Noise and vibration**						🟢	🟢	🟢		🟩	🟩	🟢	🟢	🟧	🟧	🟢	🟧	🟢
							🟡	🟢	🟢	🟢	🟧	🟧	🟡	🟡	🟥	🟧	🟡	🟩	🟡
											🟧	🟧			🟥				
F	**EMF**						🟧	🟧	🟢		🟢	🟧	🟥	🟥	🟢	🟢	🟢	🟧	🟢
							🟧	🟧	🟢	🟢	🟢	🟥	🟩	🟧	🟢	🟢	🟢		🟢
											🟡	🟧	🟧						
G	**Boat traffic**													🟧	🟧	🟢	🟧		🟢
							🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟧	🟧	🟢	🟧		🟢
H	**Lights**													🟢				🟥	🟥
							🟡		🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟧	🟥
																			🟥

Offshore Wind Energy - High Priority/High Importance

- *Static devices and sediment characteristics*. The foundation/mooring system would change the benthic habitat from sedimentary to hard structure. Scour around the foundation/mooring system may alter the distribution of sediment grain sizes in the vicinity.
- *Static devices and nearfield habitat*. The foundation/mooring system would change the benthic habitat from sedimentary to hard structure. Scour around the foundation/mooring system may alter the distribution of sediment grain sizes in the vicinity.
- *Static devices and ecosystem interactions*. A change to nearfield habitat is expected to change species composition and their interactions with one another. Underwater hard structures may serve as fish attractors (FAD effect or reef effect), attracting a different assemblage than would have been found over sand. Changes to grain size will affect infaunal organism distributions, and perhaps dependent food web relationships.
- *Static devices and cetaceans*. Cetaceans could collide with structures and become entangled in mooring lines. Lost fishing gear in the marine environment could become entangled in the mooring lines, further increasing the likelihood that cetaceans will become entangled. Behavioral changes associated with avoiding installations may result in different energetic requirements or feeding opportunities.
- *Moving devices and bats*. Bats could collide with wind turbines while flying through the area, or be injured or killed from barotraumas (i.e., pressure drop). Bats could also change their behaviors in response to wind turbines, through either avoidance of the turbines (increasing energetic requirements) or attraction to the turbines (increasing risk of collision).
- *Moving devices and birds*. Birds could collide with wind turbines while flying through the area. Birds could also change their behaviors in response to wind turbines, through either avoidance of the turbines (increasing energetic requirements) or attraction to the turbines (increasing risk of collision).
- *EMF and elasmobranchs*. EMF emitted from devices and power cables may affect elasmobranchs behavior, particularly feeding.
- *EMF and sea turtles*. EMF emitted from devices and power cables may affect orientation and behavior of sea turtles.
- *Lighting and bats*. Navigation lights on offshore wind turbines could attract insects, which in turn may attract bats. This interaction would increase the potential for collision with wind turbines.
- *Lighting and birds*. Navigation lights on offshore wind turbines could attract some species of birds and increase their potential for collision with wind turbines.

Offshore Wind Energy - Medium Impact/Important

- *Static devices and farfield habitat.* Changes in water circulation associated with the foundation/mooring system may alter the distribution and transport of sediment in farfield habitats.
- *Static devices and development of hard substrate.* The addition of hard substrate may result in attraction of the following receptors to the project area (FAD effect or reef effect): benthic invertebrates, nektonic invertebrates, resident fishes, migratory fishes, and elasmobranchs.
- *Static devices and collision with sea turtles, bats, birds.* Sea turtles could collide with structures and become entangled in mooring lines. Lost fishing gear in the marine environment could become entangled in the mooring lines, increasing the likelihood that sea turtles will become entangled. Behavioral changes associated with avoiding installations may result in different energetic requirements or feeding opportunities. Bats and birds could collide with offshore wind turbine support towers above the surface of the water.
- *Noise/vibration and bats.* Noise/vibration from wind turbines transmitted through floating platforms and from the foundation/mooring systems could cause temporary threshold shifts, hearing damage, and/or alter behavior. Noise from the turbines could attract bats to turbines, putting them at risk for collisions.
- *EMF and ecosystem interactions.* EMF emitted from devices and power cables may result in changes in ecosystem interactions by attracting or repelling some marine species, altering species composition. This interaction is listed as medium because there is a high level of uncertainty about these effects.
- *EMF and animal behavior.* EMF emitted from devices and power cables may affect orientation and behavior of benthic invertebrates, migratory fishes, cetaceans, or bats, as these species are known to be sensitive to EMF. This interaction is listed as medium because there is a high level of uncertainty about these effects.
- *Boats and marine mammals.* Boats used during construction and maintenance of offshore wind turbines could collide with or attract or repel cetaceans and pinnipeds.

3.4 PRIORITIES FOR FRAMEWORK APPLICATION

The PDT evaluated all stressor–receptor interactions to select those that would provide the most meaningful test and evaluation of the protocols framework. The following steps were taken to select these interactions:

a. Each technology-specific subteam identified key stressor–receptor interactions for that technology, based on the potential magnitude of effect and/or uncertainty.

b. The key stressor–receptor interactions were compared across technologies.

c. Those interactions that were identified as key for more than one technology were selected for a case study.

d. The PDT identified the remaining interactions for case studies based on an evaluation of possible magnitude of effects and uncertainty.

The application of these four steps resulted in the selection of 14 priority stressor–receptor interactions: five for wave, five for tidal, and four for offshore wind. Each technology-specific case study chapter begins with a detailed description of the case study technology and site and includes examples of priority interactions. For each priority interaction, a stepwise narrative outlines each of the nine steps for the *Protocols Framework*. The narratives supply details on specific information needs and the availability of existing protocols to meet those needs. The narrative also points to protocols that could be developed to cover outstanding needs. The priority interactions for each case study are supported with summary tables in Appendix A.

The 14 priority stressor–receptor interactions, by technology type, are

Wave Energy:
1. Moving Devices/Static Devices and Cetaceans
2. Static Devices/Energy Removal and Nearfield Habitat (Sediment Characteristics)
3. Static Devices/Energy Removal and Ecosystem Interactions
4. Electromagnetic Fields (EMF) and Benthic Invertebrates, Fish, Elasmobranchs, and Sea Turtles
5. Noise/Vibration and Cetaceans

Tidal Energy:
1. Moving Devices and Cetacean/Pinnipeds
2. Noise/Vibration and Cetaceans
3. Electromagnetic Fields (EMF) and Elasmobranchs
4. Moving Devices and Resident and Migratory Fish
5. Energy Removal and Sediment Transport, Wave Quality

Offshore Wind Energy:
1. Moving Devices/Static Devices and Birds
2. Static Devices and Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, Elasmobranchs
3. Moving Devices and Bats
4. Static Devices/Boat Traffic and Sea Turtles

4 OVERVIEW OF PROTOCOLS FRAMEWORK APPLICATION THROUGH CASE STUDIES

The *Protocols Framework* is very broad in scope and application, making the proof of concept and a test of its usefulness to realistic situations a critical step for this project. The team chose to test the framework on case studies for actual or likely wave, tidal and offshore wind projects on the U.S. West Coast:

- The wave energy case study is patterned after the Reedsport Ocean Power Technologies (OPT) Wave Energy Project, off the coast of Reedsport, Oregon. The details are shown in Chapter 5.
- The tidal case study is scaled to a commercial level from a proposed pilot tidal project in Admiralty Inlet, Puget Sound, Washington. The details are shown in Chapter 6.
- The offshore wind case study is a hypothetical Principle Power wind energy project located offshore of the withdrawn PG&E Humboldt WaveConnect pilot project, off the coast of Humboldt County, California. The details are shown in Chapter 7.

For each case study project, the best available information about the technology intended to be employed and the environmental resources in the proposed development area have been used, allowing for the most realistic setting for testing the utility of the *Protocols Framework.*

DISCLAIMER: *The companies referenced in this report were not involved in developing content, analysis, or conclusions. The project information presented in this report is based on the project team's summary of existing public information available at the time of its drafting, and is not endorsed by any company to be representative of any current or planned project.*

Specific attributes of each ocean technology device will dictate the potential for that device (or mooring, anchor, foundation, power cable configuration) to interact adversely with marine receptors in the project area. Similarly the specific marine animals, habitats and critical ecosystem processes in the project area will determine how vulnerable each might be to adverse interactions. It is to be expected that the outcomes of the three case studies explored in the following chapters will reflect different stressor-receptor interactions of importance, different levels of effects or impacts, and that different protocols will be recommended for development.

There are, however, certain commonalities among project sites, receptors and stressors associated with different ocean energy devices. To the greatest extent possible, these commonalities are noted and explored in order to gain predictive power and efficiencies in protocols aimed at baseline information collection as well as post-installation effects monitoring.

In order to maintain the flow and readability of the case studies, the project team elected to place certain supporting information in tables in Appendix A. In particular, information that will help the reader understand the application of the protocols framework beyond the case studies is found in two sets of tables:

a. Tables that describe the information needs for each ocean energy technology (wave, tidal, offshore wind) at a generic location, and for the specific case study site. The tables are numbered A-1 through A-5 for wave energy, A-7 through A-11 for tidal energy, and A-13 through A-16 for offshore wind energy.
b. Tables that provide additional detail on the data collection, analysis needs, and applicability of the protocols framework broadly to ocean energy development. These tables are numbered A-6 for wave energy, A-12 for tidal energy, and A-17 for offshore wind energy.

The first set of Appendix A tables that describe the information needs for baseline assessment and post-installation monitoring are designed to answer the following questions for each step in the protocols framework:

1) What information should be collected at each ocean energy project, at each step in the protocols framework?
2) What specific information should be collected at the case study site at each step in the protocols framework?

The second set of tables that describe the data needs, analysis and applicability of the framework are designed to answer these questions:

1) What types of raw data should be collected?
2) What analyses are appropriate for examining these data?
3) Over what spatial scale are the protocols, sampling design and analyses appropriate?
4) Over what ecological scale (population, community, and regional ecosystem) are the protocols, sampling design and analyses appropriate?
5) How can these protocols, sampling design, and analyses be applied to baseline assessment and to post-installation monitoring?

The tables do not include timeframes required to collect useful information for any baseline or effects monitoring. These timeframes will depend on the technology, geographic location, and amount of existing information available and, therefore, are considered project specific.

5 WAVE ENERGY CASE STUDIES

AUTHORED BY NORTHWEST NATIONAL MARINE RENEWABLE ENERGY CENTER, OREGON STATE UNIVERSITY

DISCLAIMER: *The companies referenced in this section were not involved in developing content, analysis, or conclusions. The project information presented in this report is based on the project team's summary of existing public information available at the time of its drafting, and is not endorsed by any company to be representative of any current or planned project.*

Step 1: Description of Technology and Site/Location

The case study for wave energy capture consists of the construction of 10 150-kW Ocean Power Technologies point-absorber PowerBuoys®.[2] The PowerBuoys® consist of a spar (total height 44 m[144.3] ft) oriented vertically in the water column with a basal disk 15 m (45.9 ft) wide and a float (3 m tall and 11 m diameter; 9.8 ft× 36 ft) at the surface of the water. The total above-water expression is expected to be 9 m (29.5 ft), and the total draft will be 35 m (114.8 ft). Each PowerBuoy® will have three horizontal mooring lines to subsea floats (10 m below surface). Each float will have a vertical mooring line to a square, steel-reinforced, pre-cured concrete anchor 10 m × 10 m × 8 m tall (33 ft×33 ft × by 26 ft tall) and weighing 408 metric tons (450 tons), expected to settle into the seabed and extend above the seafloor 1.7 m (5.6 ft). Each anchor holds three PowerBuoys® such that an array of 10 PowerBuoys® requires 16 anchors in a hexagonal orientation with rows of three, four, and then three buoys, oriented parallel to shore. The PowerBuoys® will be located approximately 100 m (330 ft) apart. The location and configuration of the demonstration array are shown in Figure 5-1.

The development will be approximately 2.5 mi offshore of Gardiner, Oregon in 50 – 69 m (165 – 225 ft) of water. The project boundary will encompass an area of 800 m × 800 m (0.25 mi^2). The actual footprint of the constructed array is expected to be 300 m × 400 m (1,000 ft× 1,300 ft) or approximately 0.12 km^2 (30 ac.) in the northwest corner of the project area, where depths range from 62 to 69 m (204 to 225 ft). Approximately 1.7% of the seafloor within the buoy array will be converted from sedimentary habitat to hard bottom with the installation of the 16 anchors. A full project build-out with the same anchoring scheme is expected to be similar to the 1.7% proportion. Although this is a small proportion of planar area, the vertical component of structures arising from the sea floor and the surface area of buoys and subsea floats will provide substantially harder surface.

A power/fiber optic cable will exit the bottom of each PowerBuoy®, descending to the seabed in a lazy S shape with subsurface floats attached to the cable and a clump weight at the seabed. Once on the seabed, the cable will lead to an underwater substation pod 1.9 m × 4.6 m (6 ft× 15 ft). The generated power will be transmitted to shore first via an armored subsea transmission cable, which will be trenched in the seabed to a depth of 3 to 6 ft and will follow an

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[2] Project descriptions obtained from REEDSPORT OPT WAVE PARK, FERC PROJECT NO. 12713, APPLICATION FOR A MAJOR LICENSE - JANUARY 2010.

easterly course about 2.3 statute miles until it enters the underwater outlet of an existing, underutilized 30-in. wastewater discharge pipe located about 0.5 mi from shore.

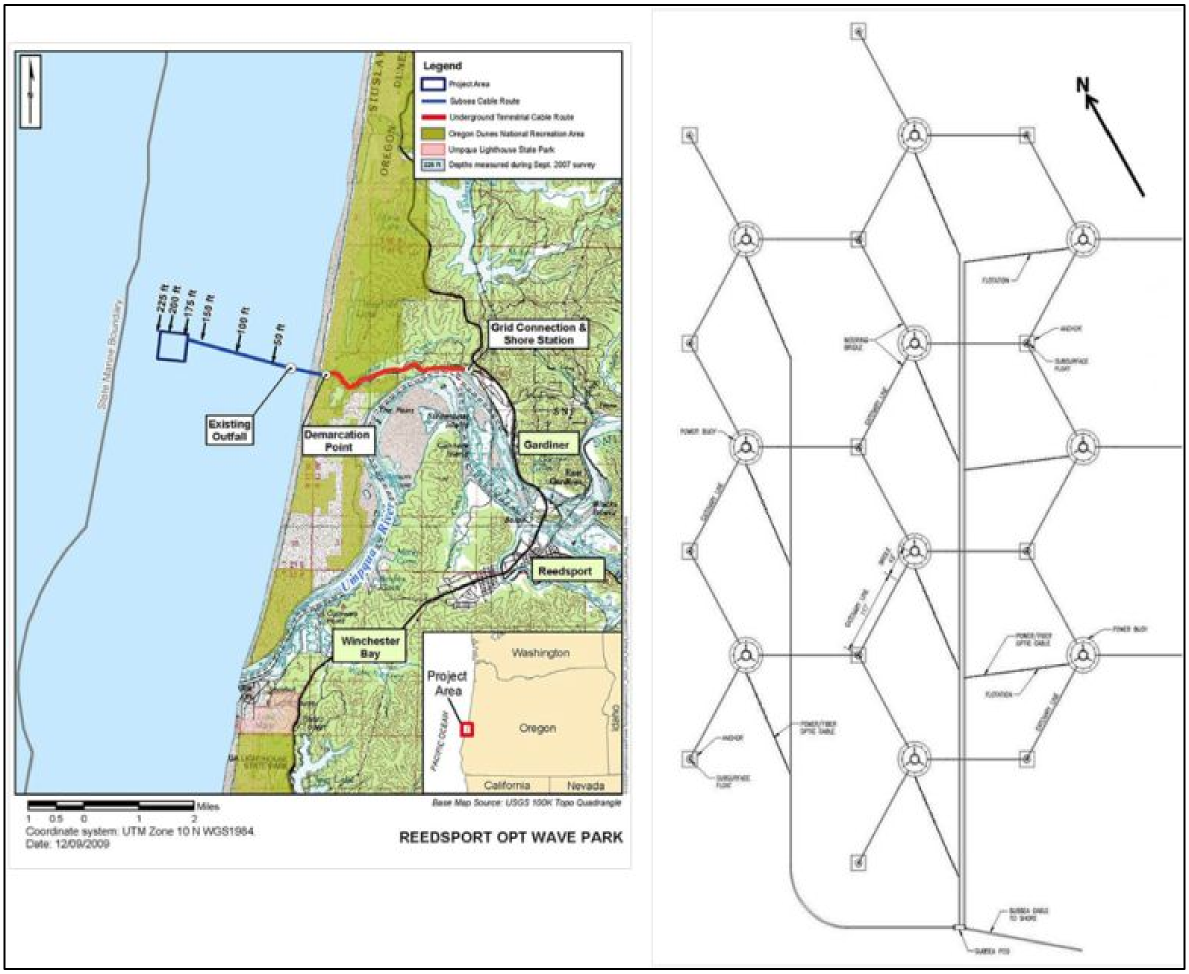

Figure 5-1. OPT Project Map: Location (left) and configuration (right) of the 10 buoy demonstration array of Ocean Power Technology PowerBuoys® proposed for Reedsport, Oregon, and used as the wave energy case study.

Each PowerBuoy® will contain 750 to 1,000 L (198 to 264 gal) of Shell Tellus Oils T hydraulic fluid. Sensors on the PowerBuoy® continuously monitor the performance of the various subsystems and surrounding ocean environment. Data are available to the shore station or a remote-control station in real time. Routine project operations and controls will occur remotely from the OPT, Inc. operations center. Construction equipment, buoy components, supplies, and maintenance vessels would be staged in Coos Bay.

The eight perimeter PowerBuoys® on the array will be lit, and the two PowerBuoys® in the middle will also have a flashing light of less intensity, as required by the USCG. The final lighting flash pattern will be developed in consultation with stakeholders and the light manufacturer to aid in depth perception, visibility in a variety of sea states, and the ability to distinguish individual PowerBuoys® at the periphery and within the interior of the array. With respect to concerns regarding attraction of birds to the lit PowerBuoys®, the USFWS recommends that OPT use a flash timing of equal to or greater than 4 sec for each individual light.

The seabed in the project area is generally flat and featureless, with depths ranging from 50 to 69 m (165 – 225 ft) in the PowerBuoy array area. The bottom is uniformly sandy with no rocky outcroppings or ledges (the side scan sonar survey identified no objects on the seabed other than sand and the sub-bottom survey found no indication of bottom structure). The effluent pipe, a concrete-encased steel pipe located approximately 0.5 statute miles from shore, was the only magnetic anomaly detected in the survey area (Sea Engineering 2007).

Sediment grain sizes in the proposed PowerBuoy array area and subsea transmission cable corridor were evaluated from 15 grab-samples collected with a Wildco Petite Ponar Grab Sampler within the PowerBuoy array area and along the subsea transmission cable route. All of the samples taken were sand, had grain sizes ranging from 171.5 to 190.8 microns, and were dark brown to black in color (Sea Engineering 2007).

Marine organisms of significant commercial value that significantly utilize the area (based on surveys conducted at the Umpqua dredge disposal site) are Dungeness crab, English sole, petrale sole, butter sole, sand dab, sand sole, northern anchovy, and ling cod (Emmett et al. 1987, Marine Taxonomic 2008). There also is a small bait fishery for sardines located in Winchester Bay (McCrae 2006). Anadromous fish that use the Umpqua River and potentially move through the project area include Chinook and Coho salmon, Steelhead, and Cutthroat trout. This area, as much of the Oregon coast, lies in the path of eastern gray whales (Eschrichtius robustus) migrating from their summer feeding grounds towards calving lagoons in Baja California, Mexico and back (Rice and Wolman 1971). Harbor porpoise (Phocoena phocoena) are also common in the area.

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

Step 2: Identify Priority Stressor-Receptor Interactions

Environmental interactions can be evaluated from several different perspectives. The project team conducted the following evaluations: 1) expert opinion, 2) regulatory, and 3) stakeholder values. This approach ensured that each interaction was viewed from the different and relevant perspectives that are known to have a major influence on the siting, licensing, and permitting process for commercial-scale ocean renewable energy projects. The expert opinion, regulatory, and stakeholder values evaluations were combined for an integrative analysis. Criteria were developed to determine protocol development priorities. The integrated list is outlined in Table 5-1.

The complete list of high- and medium-priority interactions for wave energy is identified in Chapter 3. Listed below are the interactions selected for the wave energy case studies:

- *Static/moving devices and cetaceans.* Cetaceans could collide with underwater static or moving devices or become entangled in mooring lines. Furthermore, behavioral changes associated with avoiding static or moving devices may result in different energetic requirements or feeding opportunities.
- *Static devices and nearfield habitat.* This interaction includes changes to sediment characteristics and water circulation (as the driver of changes to sediment characteristics). These are the major mechanisms by which the nearfield habitat may be changed. Anchors will change a proportion of the benthic habitat from sediment to hard bottom. Additionally, scour around the anchoring systems may alter the distribution of sediment grain sizes in the vicinity.
- *Static devices and ecosystem interactions.* This interaction is based on the change to the nearfield habitat that may change the organisms using that habitat, and thus their interactions with one another. Hard structures may serve as fish attractors, attracting a different assemblage than would have been found over sand. Changes to grain size will affect infaunal organism distributions. (Case study focuses on benthic species.)
- *EMF and elasmobranchs.* Changes to electromagnetic fields may affect elasmobranchs behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey (Gill 2005).
- *Noise/vibration and fishes, elasmobranchs sea turtles, and cetaceans.* Noise and vibration effects on fishes, elasmobranchs, sea turtles, and cetaceans are expected to have a moderate likelihood of impact. (Case study focuses on cetaceans)

Table 5-1 Wave energy- summary of matrices (see Section 3 for a summary of how these priorities were developed).

A. Static Devices			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics	🟥	🟩	⬜
Nearfield Habitat	🟥	🟧	🟧
Farfield Habitat	🟧	🟩	⬜
Ecosystem Interactions	🟥	🟧	⬜
Benthic Invertebrates	🟧	🟩	🟥
Nektonic Invertebrates	🟧	🟩	⬜
Resident Fishes	🟧	🟧	🟧
Migratory Fishes	🟧	🟧	🟧

Elasmobranchs	🟧	🟩	⬜
Sea Turtles	🟧	🟩	⬜
Cetaceans	🟥	🟥	🟥
Pinnipeds	🟧	🟧	🟧
Mustelids	🟧	🟧	⬜
Birds	🟧	🟥	🟧
B. Moving Devices			
	Expert Opinion	Regulatory	Stakeholder Values
Plankton	🟧	🟧	⬜
Sea Turtles	🟧	🟧	⬜
Cetaceans	🟧	🟥	🟥
Pinnipeds	🟧	🟧	🟧
Mustelids	🟧	🟧	⬜
Birds	🟧	🟧	🟧
C. Energy Removal			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics	🟧	🟧	⬜
Water Circulation	🟧	🟩	🟧
Water Chemistry	🟧	🟩	⬜
Nearfield Habitat	🟧	🟩	⬜
Farfield Habitat	🟧		⬜
Ecosystem Interactions	🟧	🟧	⬜
Benthic Invertebrates	🟧	🟩	⬜
D. Chemical Release			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics	🟩	🟩	🟥
E. Noise and Vibration			
	Expert Opinion	Regulatory	Stakeholder Values
Resident Fishes	🟧	🟧	🟥
Migratory Fishes	🟧	🟧	🟥
Elasmobranchs	🟧	🟧	⬜
Sea Turtles	🟧	🟧	⬜
Cetaceans	🟧	🟥	🟥

F. EMF			
	Expert Opinion	Regulatory	Stakeholder Values
Ecosystem Interactions	🟧	🟧	⬜
Benthic Invertebrates	🟧	🟧	🟥
Resident Fishes	🟩	🟩	🟥
Migratory Fishes	🟧	🟥	🟥
Elasmobranchs	🟥	🟩	🟥
Sea Turtles	🟧	🟧	⬜
G. Boat Traffic			
	Expert Opinion	Regulatory	Stakeholder Values
Cetaceans	🟧	🟧	⬜
Mustelids	🟧	🟧	⬜

H. Lights			
	Expert Opinion	Regulatory	Stakeholder Values
Birds	🟧	🟥	🟧

5.1 MOVING DEVICES/STATIC DEVICES AND CETACEANS

Wave Energy High Priority Interaction #1

Reedsport, Oregon

Stressor: Moving/Static Devices

Receptor: Cetaceans

Step 1: Description of Technology and Site/Location

This case study is based on wave energy technology deployed in Reedsport, Oregon. Detailed information on the project is included at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

High priority/high importance interactions were developed as described in Chapter 3. This example reviews the specific information below.

> **Stressor: Moving/Static Devices Priority: Medium/High**
> **Issue:** Cetaceans could collide with moving components of wave energy converters while migrating through and/or feeding in the area; similarly, they could collide or become entangled in static components (e.g., mooring lines, anchors).

Step 3: Spatial and Temporal Scale of Stressor

For the Ocean Power Technologies wave energy case study, wave energy capture devices and the associated anchors and subsea cables are the physical stressors that could affect cetaceans (receptor) in the project area. The three-dimensional footprint of the 'static device' stressor is as follows:

- Array footprint for 10 buoys: 0.12 km^2 (30 ac.)
- Anchor area: 625 ft^2 each, 10,000 ft^2 total
- Distance between anchors: 100 m
- Array will be 1.3 km long in an east–west orientation × 1 km wide

The temporal scale or duration is constant, except for cessation of moving components during shutdown or maintenance. The magnitude of movement of moving components will also vary with wave height. All components will remain present throughout the deployment.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

The best sources for distributional data of ESA-listed and MMPA-protected species are found in Barlow et al. (2009, 2010) and Forney (2007). ESA-listed species of cetacean potentially present in the project area include humpback, blue, fin, sei, sperm, and Southern Resident killer whale. Although the ESA-listed species have not been observed in the project area, distributional studies suggest that some may occur there. Southern Resident killer whale have been observed south of the project area in winter, and it is likely that they may pass through this nearshore area of the OPT project. In summer 2011, humpback and blue whales were observed as close as 3 mi offshore of Newport and Depoe Bay (Lagerquist, pers. comm.), so it is likely that similar patterns exist off Reedsport.

MMPA-protected species of cetacean that have been observed in the project area include gray, minke, and killer whales, harbor and Dall's porpoise, northern right whale dolphin, Pacific white-sided dolphin, Risso's dolphin and short-beaked common dolphin. Although gray whale migration tracks have not been identified off Reedsport, it is likely that they would be similar in terms of distance offshore and seasonality to those off Newport (Ortega-Ortiz and Mate 2008). Minke whales, northern right whale dolphin, Pacific white-sided dolphin, Risso's dolphin and short-beaked common dolphin tend to be further offshore so may only potentially occur in the project area.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for changes to marine mammals would be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Ocean Power Technologies Wave Energy Project.

Scientific Thresholds

Baseline and effects monitoring should detect if the following scientific thresholds are exceeded for marine mammals that occur in the Ocean Power Technology Project area:

1. Strikes with buoys or mooring lines resulting in injury or death, thereby causing or contributing to population declines; or
2. Significant proportion of population (as a function of the existing population status) being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities; increase in migration distances or movement to areas that may result in greater potential predation).

Regulatory Thresholds

Baseline and effects monitoring should detect if the following regulatory thresholds are exceeded for marine mammals that occur in the Ocean Power Technology Project area:

1. For species listed as threatened or endangered under the ESA, the threshold is take or injury of one individual or harassment by presence of devices or traffic to devices.
2. Under the MMPA, the threshold is take of listed species through injury or mortality. MMPA-protected species of cetacean that have been observed in the project area include gray, minke, and killer whales, harbor and Dall's porpoise, northern right whale dolphin, Pacific white-sided dolphin, Risso's dolphin, and short-beaked common dolphin.

Step 6: Baseline Information Monitoring Needs

Information will need to be obtained from existing sources or collected through new efforts to document the baseline conditions against which the effects that static and dynamic devices may have on cetaceans will be evaluated. New data collection may include monitoring migration pathways and feeding behavior. An information need is to determine how much of these types of data are needed to establish what is the range of baseline behavior expected to be observed in the project area. A second baseline information product may be modeling collision and encounter rates based on baseline observations and what is expected in terms of the spatial extent of the stressor.

Step 7: Effects Monitoring Information Needs

Studies will likely be needed to evaluate the effects that static and dynamic devices may have on cetaceans. This may include modeling collision and encounter rates based on baseline studies, continuing to monitor migration pathways and feeding behavior to detect avoidance/attraction behavior, and monitoring interactions, possible collisions, and possible entanglement. An effects monitoring information need will be to determine the amount of data needed to assess whether a detected change in behavior of animals in the project area is actually due to the project installation/operation. In general, the *intensity* of the stressors will not vary greatly, but the concern for additional entanglement from debris (ropes, derelict fishing gear) that may become entangled in the mooring cables could be problematic in different areas and should be periodically monitored.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

Sampling approaches for marine mammals are generally well developed, but several competing approaches have advantages and disadvantages that are dependent upon study objectives (Macleod et al. 2010; see table 6-2, this report, page 82). For wave energy devices, the selected approaches may be narrowed due to the proximity to the coast, acoustic noise, or rough weather conditions. Ortega-Ortiz and Lagerquist (2009) identified the basic existing protocols available for monitoring cetaceans in the vicinity of wave energy devices. In order to collect baseline information about marine mammals that may occur in the vicinity of the OPT study site, the following monitoring protocols can be used to determine the diurnal, seasonal, and annual variability in marine mammal distribution and habitat use.

***Visual approaches*:** Although a variety of published studies (e.g., Barlow et al, 2009, 2010) have used boat-based studies or aerial surveys, these are expensive, time consuming, and weather dependent, and may not be of appropriate scale for the smaller nearshore areas where wave energy devices will be deployed. Ortega-Ortiz and Mate (2008) used shore-based theodolite tracking from moderately high vantage points on land; they were able to successfully define tracks of the different migration groups moving along the coast. Ortega-Ortiz and Lagerquist (2009) concluded that this was the best approach for large whales. It may require high vantage points such as headland, but it is also possible to construct towers or other means of gaining the needed altitude for such tracking.

***Passive Acoustic Monitoring*:** Passively sensing the acoustic emissions from marine mammals can be used to identify presence/absence and also patterns of abundance. It is the best technique for toothed whales (Odontocetes), but may not be useful for gray whales, which vocalize less during migration and feeding. Various devices are available to conduct such work at the high frequencies used by marine mammals and typically target 100–150 kHz for harbor porpoise and up to 60 kHz for dolphins (Mellinger et al. 2007). Standards for marine mammal work generally use continuous recording of low-frequency sound and intermittent recording of high-frequency sound (due to storage and battery limitations). Sampling should ideally be done on diel, seasonal, and storm temporal scales (Mellinger et al. 2007).

Study Design for Baseline Monitoring of Cetaceans for the Ocean Power Technologies Wave Power Project

Shore-based theodolite sampling following the techniques of Ortega-Ortiz and Mate (2008) could be conducted during the northward and southward migratory season for one year prior to the OPT deployments to address gray whale distribution and to observe any other large whales present along with their movement patterns. Passive acoustic monitoring following the approach of Mellinger et al. (2007) could also be conducted during the year prior to deployment to determine other species of cetacean present in the deployment area.

Protocols That Need Development/Testing

The baseline protocols above are well developed, but several additional tools could be further developed to address needs for effects monitoring. One approach is with telemetry. Tagging with satellite, acoustic, or other “smart” tags can be useful to provide results but have several drawbacks. For example, tags can be deployed on only a small percentage of the population, and there is no guarantee that the tagged animals will visit the vicinity of the project site. Monitoring tracks of gray whales with the resolution required will need the accuracy of quick-fix Global Positioning System tags, which must be recovered to retrieve the data. Other tags, such as acoustic transponders with receivers affixed to the wave energy devices, are also possible; emplaced recorders could serve dual purposes to detect tagged salmonids, sturgeon, and other fishes and mobile marine organisms.

Selecting a Protocol for Baseline Monitoring of Cetaceans for the Ocean Power Technologies Wave Power Project

The protocols noted above under Study Design are those currently available that will yield useful results.

Step 9: Effects Monitoring Protocols

Existing Protocols

In order to assess the potential effect of wave energy projects on marine mammals, it will be necessary to have the data from baseline monitoring to determine the distribution, abundance, migratory pathways, and habitat use of marine mammals. Many of the protocols from the baseline studies will need to be continued to statistically detect change in the parameters from the baseline study. Frankel (2005) was able to detect altered movement patterns in gray whale confronted with a sound signal by using two adjacent shore-based theodolite samplings to extend the range of detection and infer changes to behavior; extension and improved development of this technique may be useful for detecting change (i.e., may be a candidate for additional protocol development). Collision modeling based on distribution and habitat use (see Wilson et al. 2007) will be useful, as will direct and indirect observation on aggregation, avoidance, and entanglement.

Protocols That Need Development/Testing

As noted above, telemetry approaches like those for monitoring may be useful. In addition, scanning sonar systems that could be mounted to wave devices and identify marine mammal targets would also be possible. Although limited by available ambient light, direct video observation of fine-scale behavior around devices is possible using “critter-cams” (Williams et al. 2000) mounted on species shown to be attracted to the devices; this approach may successfully demonstrate interaction with devices. Finally, by using multiple recording hydrophones and sound propagation modeling, it may be possible to estimate locations of marine mammals (Tieman et al. 2004). None of these approaches are sufficiently well developed to use at this time and will require research before being implemented to use around wave energy devices.

5.2 STATIC DEVICES/ENERGY REMOVAL AND NEARFIELD HABITAT (SEDIMENT CHARACTERISTICS)

Wave Energy High Priority Interaction #2

Reedsport, Oregon

Stressor: Static Devices/Energy Removal

Receptor: Nearfield Habitat

Step 1: Description of Technology and Site/Location

This case study is based on wave energy technology deployed in Reedsport, Oregon. Detailed information on the project is included at the beginning of this chapter in the Technology and Site Characteristics section.

Step 2: Identify Priority Stressor-Receptor Interactions

High priority/high importance interactions were developed as described in Chapter 3. This example reviews the specific information below.

Stressor: Static Devices **Priority: High**
Issue: This interaction includes changes to the nearfield habitat, as changes to sediment characteristics are the major way by which the nearfield habitat will be altered. Anchors will change a small proportion of the benthic habitat from sedimentary to hard structure. Scour around the anchoring systems can alter the distribution of sediment grain sizes and other sediment characteristics in the vicinity.

Stressor: Energy Removal **Priority: Medium**
Issue: Removal of energy from the area by device operation may alter the distribution of sediment grain sizes in the vicinity.

Step 3: Spatial and Temporal Scale of Stressor

For the Ocean Power Technologies wave energy case study, wave energy capture devices and the associated anchors and subsea cables are the physical stressors that could affect sediment (receptor) in the project area. The three-dimensional footprint of the ‘static device’ stressor is as follows:

- Array footprint for 10 buoys: 0.12 km^2 (30 ac.)
- Anchor area: 625 ft^2 each, 10,000 ft^2 total

In terms of the energy removal, it is not yet known what the spatial extent of the energy removal will be; that is, how far the energy removal ‘shadow’ will persist.

The temporal scale of the stressor is temporary and short term for potential effects from cable lying. The temporal scale of the stressor of the large anchors in the water column is for the duration of the project. The temporal scale of the energy removal stressor is constant for the duration of the project as well but may vary based on the operation of the PowerBuoys®.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to conduct an effects analysis, it is necessary to determine the spatial and temporal extent of the interaction between devices and sediment. Because these devices will be placed in sedimentary habitat, there will be 100% overlap between the area of device deployment and the potential area of effects to sediment. Typically, waves have strong influences on bottom currents at depths of 50 m and less (Largier et al. 2008); thus, the reduction of wave energy in this zone could affect bottom currents and sediment distribution. Furthermore, the effects of the stressor may go beyond the spatial extent of the installation, so the spatial extent of the stress on the sediment receptor will be greater than the project footprint. Sand adjacent to an artificial reef installed in La Jolla, California, at 13 m water depth was scoured to a depth of 20 to 40 cm as far as 15 m from the reef (Davis et al. 1982). Grain size analysis of sediment collected along a transect from Oil Platform *Eva* off Huntington Beach, California, in 18 m water depth indicated coarse sand to 20 m from the platform with very fine sand beyond (Wolfson et al. 1979). In some cases, the project footprint surrounded by a buffer of 3 km may be considered the impact area (Vanerman and Stienen 2009).

The temporal overlap of the stressor and receptor is again 100% for this interaction as the devices are installed in the sediment. However, there may be periods when the intensity of the stressors is greater, such as during installation of anchors, burial of cables, or removal of devices. Likewise, natural seasonal dynamics may result in differences in the relative effect of the stressors on the receptor.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for changes to sediment distribution or composition should be designed to detect when scientific thresholds are exceeded as a result of the Ocean Power Technologies Wave Energy project.

Scientific Thresholds

Baseline and effects monitoring should ideally be designed to be able to detect if the following scientific thresholds are exceeded for sediment dynamics and or composition in the OPT project area relative to reference locations:

1. Transition from mud to sand around anchors/within the array
2. Transition from unconsolidated sediment to hard-surface anchors within the array
3. Deposition of fine sediment in new areas within/around the array
4. Significant change in sediment depth (locally due to scour or farfield due to changes in overall dynamics).

Regulatory Thresholds

No regulatory thresholds exist; however, the *Clean Water Act*, the *Endangered Species Act*, and Oregon’s Statewide Planning Goals & Guidelines: Goal 17: Coastal Shorelands could apply.

Section 404 of the *Clean Water Act* (CWA) established a program to regulate dredging and/or filling in U.S. waters. Section 404 acknowledges that dredging and filling may change sediment dynamics in multiple ways across different environments; however, no thresholds are set regarding sediment characteristics. Other sections of the CWA set thresholds for sediment contamination levels; however, contaminants are not addressed in this stressor–receptor interaction. The CWA also stipulates (in Section 304.f.2.F) that if a project brings about a change that allows accumulation or different distribution of a pollutant; then that project may be held responsible. If the project results in changes to estuary dynamics (for example) that might affect an endangered species, then the ESA could be applicable.

Oregon's Statewide Planning Goals & Guidelines Goal 17: Coastal Shorelands: OAR 660-015-0010(2) gives guidance that land use plans shall 1) inventory sedimentation sources; and 2) minimize man-induced sedimentation. However, no regulations regarding changes to marine sediment characteristics exist.

Step 6: Baseline Information Monitoring Needs

There is limited information about the seasonal and interannual dynamics of sediment in the area. A baseline bathymetry survey of the nearshore area shoreward of the site was conducted along with regular observations of the topography and shoreline and video observations of the submerged sand bar features (Özkan-Haller et al. 2009). These observations helped characterize the baseline variability over 1 year of nearshore areas at the site and the adjacent beach. Acoustic backscatter surveys have been conducted in nearby areas as part of the Oregon Territorial Sea mapping effort; however, the project site itself has not been mapped as part of the process. It is uncertain what surveys have been conducted at the site. Box core samples have been collected at the site and at a reference location and grain-size and total organic carbon analyses have been conducted on the samples (Henkel 2011). Information needs include data on seasonal and interannual sediment characteristics offshore in the project area.

Step 7: Effects Monitoring Information Needs

Effects monitoring should assess changes to sediment distributions or characteristics in the project area and at a reference area. The shelf is narrow at the project location, and fine sand is present from the nearshore to beyond project depth (60 m). The shelf widens north of the project location, so a reference site to the south would be more appropriate. Understanding the temporal and spatial scale of sediment movement under natural conditions (as assessed in baseline monitoring) is critical to determining if changes observed in the short term are permanent or exist only until the next storm rearranges the system. In the long-term perspective, the transition from mud to sand or the deposition of fine sediments may occur only between storms and the system may be reset after each event.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

In order to collect baseline information about sediment dynamics that may occur in the vicinity of wave energy capture installation, one or more of the following monitoring protocols can be used to determine seasonal and interannual variability in the composition and distribution of sediment. Techniques that have been used traditionally to study and classify the benthic environment include sediment-profile cameras, side-scan sonar, sediment grabs and cores, acoustic sub-bottom profiling, and acoustic backscatter (Rhoads et al. 1994). Side-scan sonar, sub-bottom profiling, and acoustic backscatter provide continuous broad areal maps of the bottom sediment types while sediment-profile cameras and sediment-sampling devices provide descriptions of the benthic environment and sediment characteristics at points on the seafloor. In addition, sediment-sampling devices collect sediment that can be used for a variety of tests to determine sediment characteristics including grain size, density, porosity, redox, and total organic carbon. A wide variety of surface-sediment sampling tools are reviewed in Fields-Capri and Schumacher (2004).

Study Design for Baseline Monitoring of Sediment Dynamics

Broad areal coverage surveys, such as multibeam sonar depth and acoustic backscatter mapping, of the proposed installation site may be helpful baseline information.

For sediment-profile cameras and sediment grab sampling, a grid of sampling stations or a random distribution of sampling stations (e.g., determined using a randomized, tessellated, stratified sampling design used by the Environmental Protection Agency Environmental Monitoring and Assessment Program (EMAP); Stevens and Olsen 2004) should ideally be established such that a number of stations, varying distances from the proposed installation are sampled.

Protocols That Need Development/Testing

The above-described protocols are well established for monitoring sediment characteristics and dynamics. No new protocols need development.

Selecting a Protocol for Baseline Monitoring of Sediments for the Ocean Power Technologies Wave Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may only have the statistical power to detect change at the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean or open ocean), is also expected to have a significant influence on the type of monitoring that is feasible. Because the area of the proposed OPT PowerBuoy® installation is small, the effect is expected to be localized. It is recommended that sediment grab sampling be conducted in a regular or random grid at the proposed installation location at least once before deployment. The grain size of the sediment collected in the grab samples should be analyzed. Any other sediment properties of interest may also be analyzed; however, these are often correlated with grain size.

Step 9: Effects Monitoring Protocols

The effects monitoring protocols would be mostly the same as baseline monitoring protocols. However, broad aerial surveys within the project array likely will not be possible post-installation. Such surveys could be conducted inshore or down current of the array. Sediment collection and grain-size analysis varying distances and directions from the project location will indicate whether the project has had an effect on sediment dynamics. Thus, it is recommended that grab sampling be conducted as the primary effects monitoring. These grab samples may not be able to be taken within the array. It is recommended that they be taken at least within 100 m of the edge of the array and closer if possible. Post-installation sampling may be conducted once per year to assess long-term trends; however, ad hoc sampling after storm events could help determine potential installation effects in the context of storm-induced changes to the system. If changes in grain sizes are detected in grab samples, enhanced monitoring protocols may be employed to assess potential changes to sediment characteristics which may have ecological consequences for which regulations are neither in place nor have sufficient scope to guard against.

5.3 STATIC DEVICES/ENERGY REMOVAL AND ECOSYSTEM INTERACTIONS (FOCUSED ON BENTHIC INVERTEBRATES; SEE OFFSHORE WIND CASE STUDY FOR SCALING UP)

Wave Energy High Priority Interaction #3

Reedsport, Oregon

Stressor: Static Devices/Energy Removal

Receptor: Benthic Invertebrates

Step 1: Description of Technology and Site/Location

This case study is based on wave energy technology deployed in Reedsport, Oregon. Detailed information on the project is included at the beginning of this chapter in the Technology and Site Characteristics section.

Step 2: Identify Priority Stressor-Receptor Interactions

High priority/high importance interactions were developed as described in Chapter 3. This example reviews the specific information below.

Stressor: Static Devices **Priority: Medium**
Issue: This effect of static devices on benthic invertebrates is likely due to changes to the nearfield habitat via changes to sediment characteristics and introduction of new hard substrate.

Stressor: Energy Removal **Priority: Potential Effect**
Issue: Removal of energy from the area by dynamic components of the devices may affect benthic invertebrates by altering sediment characteristics in the vicinity. Reduction in wave-induced bottom velocities could reduce the flux of dissolved and particulate material to benthic organisms and have a small effect on benthic invertebrate feeding and reproductive success.

Step 3: Spatial and Temporal Scale of Stressor

For the Ocean Power Technologies wave energy case study, wave energy capture devices and the associated anchors and subsea cables are the physical stressors that could affect sediment (receptor) in the project area. The three-dimensional footprint of the ‘static device’ stressor is as follows:

- Array footprint for 10 buoys: 0.12 km^2 (30 ac.)
- Anchor area: 625 ft^2 each, 10,000 ft^2 total

In terms of the energy removal, it is not yet known what the spatial extent of the energy removal will be; that is, how far the energy removal ‘shadow’ will persist.

The temporal scale of the stressor is temporary and short term for potential effects from cable lying. The temporal scale of the stressor of the large anchors in the water column is for the duration of the project. The temporal scale of the energy removal stressor is constant for the duration of the project as well but may vary based on the operation of the PowerBuoys®.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to conduct an effects analysis, it is necessary to determine the spatial and temporal extent of the interaction between devices and benthic invertebrates. Because these devices will be placed in sedimentary habitat, there will be 100% overlap between the area of device deployment and the potential area of effects to sediment-associated benthic invertebrates. Typically waves have strong influences on bottom currents at depths of 50 m and less (Largier et al. 2008); thus, the reduction of wave energy in this zone could affect bottom currents. Reduction in wave-induced bottom velocities could alter sediment distributions, food delivery, mixing of eggs and sperm, or larval delivery, which could affect species distributions. The effects of the stressor may go beyond the spatial extent of the installation, so the spatial extent of the stress on the sediment receptor will be greater than the project footprint. Studies of offshore platforms in the Mediterranean indicated that benthic infaunal assemblages varied with distance from the platform, but the spatial extents of these differences varied with depth of the platform (90 m versus 30 m; Terlizzi et al. 2008) and over time (Manoukian 2010).

The temporal overlap of the stressor and receptor is again 100% overlap for this interaction, and the devices are installed in the sediment. However, there may be periods when the intensity of the stressors is greater, such as during installation of anchors, burial of cables, or removal of devices. Likewise, natural seasonal dynamics may result in differences in the relative effect of the stressors on the receptor.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for changes to benthic invertebrate distribution or composition should be designed to be able to detect changes that exceed the natural seasonal or inter-annual variability in the system, as scientific thresholds do not currently exist for such metrics.

Scientific Thresholds

Baseline and effects monitoring for changes to benthic invertebrate distribution or composition should ideally be designed to detect when scientific thresholds are exceeded as a result of the Ocean Power Technologies Wave Energy project.

Regulatory Thresholds

Regulatory thresholds do not exist for changes to benthic invertebrate species.

Step 6: Baseline Information Monitoring Needs

There is limited information about the seasonal and interannual dynamics of benthic invertebrates in the area. The greatest effort has been placed in investigating the abundances and movements of Dungeness crab in the area (Terrill et al. 2010). Terrill et al. (2010) additionally conducted series of small otter trawls (4m-wide net) in 2009 at the project location and reported the epibenthic invertebrates captured by the trawl. Henkel (2011) surveyed infaunal invertebrates using a box corer at the Reedsport site and a nearby reference location in 2011; this study also conducted small beam trawl (2m-wide net) tows of the project location and reference site to collect epibenthic invertebrates as well as fishes. However, because these various surveys with different gear types have each been conducted only once at the project site, they do not reveal temporal dynamics of the benthic invertebrate assemblages at the site. The degree of temporal variability in species or assemblages of interest is necessary to discern project-related changes.

Step 7: Effects Monitoring Information Needs

To evaluate the effect of devices and/or energy removal benthic invertebrates in the project area, information about their distribution, habitat associations, behaviors, and food habits would likely need to be collected. The degree of temporal and spatial variability in species or assemblages of interest needs to be characterized before project-related changes can be evaluated. Thus, baseline samples should ideally be obtained across seasons, depths, and latitude. Reference sites could be established to evaluate temporal changes at locations reasonably distant from the project site. The shelf is narrow at the project location, and fine sand is present from the nearshore to beyond project depth (60 m). The shelf widens north of the project location, so reference sites to the south would be most appropriate because the benthic habitat is most similar; however, a reference site to the north may also be necessary to evaluate changes related to water circulation patterns because the prevailing winds and their effects on the water column change direction seasonally in Oregon.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

In order to collect baseline information about benthic invertebrates that may occur in the vicinity of wave energy capture installation, one or more of the following monitoring protocols can be used to determine seasonal and interannual variability in the composition and distribution of benthic invertebrates. A variety of different techniques can be employed to either survey whole assemblages of organisms or to target specific species of interest.

Sampling Assemblages

Visual Surveys. Epibenthic invertebrate presence, density, size, and temporal distribution can be ascertained using visual survey methods (Somerton and Glendhill 2005). Specific methods include SCUBA or diver-operated video transects (Martin and Lowe 2010), towed video transects using sled-mounted cameras (Sheehan et al. 2010), manned-submersibles (Yoklavich and O’Connell 2008), and remotely operated vehicle (ROV) transects (Pacunski et al. 2008).

Bottom Trawls. Bottom trawling using beam trawls or otter/shrimp trawls can be effective to inventory epibenthic invertebrates. The 2-m beam trawl is routinely employed for the collection of epifaunal samples from a variety of sediment types and is designed to sample at and just above the surface of the seabed. It performs reliably on soft and coarse sediment; although whether or not quantities of individuals are sampled reliably with this equipment is still under debate (Callaway et al. 2003). Its small size makes it easy to deploy and usually results in the collection of a manageable sample size (Ware and Kenny 2011); multiple tows will be necessary to achieve adequate statistical power (Terrill et al. 2010). For each tow, an average towing speed of 1.5 knots should be maintained for duration of 5 to 10 min, usually depending on the density of organisms. The sample should be sufficiently large enough to adequately characterize the resident epifaunal assemblage.

Grabs. The U.S. Environmental Protection Agency (EPA) initiated the Environmental Monitoring and Assessment Program (EMAP) in 1990 to develop, test, and validate environmental monitoring methods (U.S. EPA 1990) for sampling benthic macrofaunal invertebrates. Originally the EMAP protocol required three to five replicate samples per station (a number that is commonly seen in the literature). However, studies have shown that a single sample per station is sufficient (Summers et al. 1992; Macauley et al. 1993); thus, the protocol has been modified, and now replicates are optional (U.S. EPA 2001). The number of sampled stations per site will vary based on the degree of expected heterogeneity of the site. One station per 2 km^2 is often used. Analysis of the cost effectiveness of benthic sampling conducted through the EMAP found that using a smaller sampler (0.01 m^2 versus 0.1 m^2) and a larger mesh size (1.0 mm versus 0.5 mm) is the least costly and was effective at describing taxonomic composition and abundance. To maximize cost efficiency and minimize small-scale end point variability in future comparative studies, they recommend taking one 0.1-m^2 benthic macrofaunal sample at each station (which may be subsampled if desired) and sieving through 1-mm mesh (Ferraro et al. 2006). Box corers and Van Veen grabs are two commonly used 0.1-m^2 collection devices. Box-corers penetrate farther into the sediment than grabs and hence sample deeper dwelling benthic infauna. Furthermore, box corers retain the stratigraphy of the collected sediment, so analysis of different layers can be conducted, if desired.

Sampling Species of Interest

Trapping. Trapping can be used to evaluate presence, density, size, and temporal distribution of epibenthic invertebrates such as crabs and sea stars.

Study Design for Baseline Monitoring Benthic Invertebrates

To survey infaunal invertebrates in the sedimentary habitat, a grid of sampling stations or a random distribution of sampling stations or transects (e.g., determined using a randomized, tessellated, stratified sampling design used by EMAP; Stevens and Olsen 2004) should be established such that a number of stations/transects, varying distances from the proposed installation are sampled. Samples should be taken with a 0.1-m^2 grab sampler, sieved on 1-mm mesh, and identified to the lowest possible taxonomic level. These stations should initially be sampled seasonally to assess baseline spatial and temporal variability.

To sample epifaunal invertebrates in the sedimentary habitat of the OPT site, a trawl or towed camera could be used. Two reference locations in addition to the project location should be selected, and sampling stations should be based on a regular or random sampling grid as in the core sampling.

Protocols That Need Development/Testing

The above-described protocols are well established for monitoring benthic species. No new protocols need development.

Selecting a Protocol for Baseline Monitoring of Benthic Invertebrates for the Ocean Power Technologies Wave Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may have the statistical power to detect change at only the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean, or open ocean), are also expected to have a significant influence on the type of monitoring that is feasible. Because the area of the proposed OPT PowerBuoy® installation is small, the effect is expected to be localized.

For baseline sampling of infaunal invertebrates, box core sampling should be conducted in a regular or random grid at the proposed installation location and at two or more reference locations over different seasons for at least 1 year before deployment. Organisms should be sieved on 1-mm mesh and identified to the lowest possible taxonomic level. The grain size of the sediment collected in the grab samples also could be analyzed.

For baseline sampling of epibenthic invertebrates, the 2-m beam trawl is recommended rather than towed camera surveys initially, as collection of the samples will greatly aid in identification of organisms. Trawls should be conducted in a regular or random grid at the proposed installation location and at two or more reference locations over different seasons for at least 1 year before deployment. Pairing of trawl and visual surveys initially may enable the future use of visual surveys only, once a level of confidence in identification of organisms observed on camera is reached.

Step 9: Effects Monitoring Protocols

For infaunal community structure, effects monitoring are similar to baseline monitoring protocols. Infaunal organism and sediment collection should be taken within, and varying distances and directions from, the project location. If grab samples cannot be taken within the array, it is recommended that they be taken at least within 100 m of the edge of the array and closer if possible. Post-installation sampling could also be conducted at the reference location. If seasonal variation is observed in baseline sampling, sampling should be conducted seasonally post-installation. However, if baseline sampling indicates there is no seasonal variability in the infaunal invertebrate assemblages, effects monitoring may be conducted annually.

Evaluation of epifaunal organisms should consist of additional sampling for post-installation effects monitoring. Beam trawl surveys should continue to be conducted; however, like coring, it may be possible to conduct tows only outside of the array. Within or near the array, traps may be effective for sampling specific epibenthic invertebrate species.

When possible, visual surveys of subsurface components of the devices (particularly concrete anchor blocks) should be conducted to evaluate the degree of colonization of hard structures by invertebrates that may not have been present in the immediate area (sedimentary substrates) before. These surveys can be conducted via SCUBA (depending on depth) or with ROVs. This evaluation may be particularly important because colonization of structures by seaweeds and invertebrates could attract novel fish or even turtle species to the area. These species may prey on resident fish and invertebrates, inducing larger ecosystem scale effects.

To assess if project related effects have occurred, it will be necessary to determine if the assemblage of species or if the densities of species at the project location are significantly different from reference locations and outside the bounds of the natural variability observed at the site prior to installation.

5.4 ELECTROMAGNETIC FIELDS AND BENTHIC INVERTEBRATES, FISHES, ELASMOBRANCHS AND SEA TURTLES

Wave Energy High Priority Interaction #4

Reedsport, Oregon

Stressor: EMF

Receptor: Species of Concern

Step 1: Description of Technology and Site/Location

This case study is based on wave energy technology deployed in Reedsport, Oregon. Detailed information on the project is included at the beginning of this chapter in the Technology and Site Characteristics section.

Step 2: Identify Priority Stressor-Receptor Interactions

High priority/high importance interactions were developed as described in Chapter 3. This example reviews the specific information below.

> **Stressor: Electromagnetic Fields (EMF) Priority: Medium**
> Energy-generating machines and power cables produce electromagnetic fields (EMF). Although the electrical field emanating from a device maybe be rapidly damped in seawater in some circumstances or propagated to significant distances if the local geology provides an electrically resistive waveguide within the seafloor and power cables are commonly insulated to prevent leaking of electric fields, the magnetic field can extend out from the generator and cables and can induce an electric field in seawater. Furthermore, over the lifetime of operation of an installation, pin-hole leaks and physically compromised insulation and armoring could short out and stop carrying current (Bull, A. Scarborough. 2012. pers. comm.) or provide a potential pathway for electric current leakage from an otherwise shielded cable. Elasmobranchs use EMFs to locate prey and conspecifics; migratory fishes and sea turtles may use the earth's magnetic fields for navigation. It has also been suggested that some benthic invertebrates, such as Dungeness crab, are sensitive to EMF; other species may have alterations to embryonic development from EMF exposure. Cables can be found in the water column from devices to the sea floor and along the seabed, potentially buried, to bring power to shore.

Step 3: Spatial and Temporal Scale of Stressor

For the Ocean Power Technologies wave energy case study, wave energy capture devices and the associated anchors, junction boxes, and subsea cables may alter electromagnetic fields, serving as physical stressors that could affect species of concern (receptors) in the project area. The three-dimensional footprint of the static device stressor is as follows:

- Array footprint for 10 buoys: 0.12 km^2 (30 ac.)

- Water depth:60–65 m (important for vertical length of electrical cable)
- Anchor area: 625 ft^2 each, 10,000 ft^2 total
- Distance between anchors: 100 m
- Array will be 1.3 km long in an east–west orientation × 1 km wide
- Transmission cables will run to shore; AC power is generated in the PowerBuoys®, then converted to DC and then to 3-phase DC power when leaving the PowerBuoy®. It goes to a subsea pod and then to a 13.8-kV subsea power cable to shore.

The temporal scale or duration of the operating system is constant, except during shutdown or maintenance, but changes in wave height (and thus power generation) will change EMF magnitude over time, resulting in complexity of the fields; this intermittency will result in a different form of the stressor. With offshore wind, for example, power generation will be variable. There is also a geometry—the direction, orientation of field, and how it propagates out in three dimensions. Magnetic fields generated, for example, by cables, can interact with the local magnetic field and be additive or cancel out, depending on direction, and thus need to be put in the context of the measured background field.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

For each species of concern (here, including elasmobranchs, benthic invertebrates, fishes, and sea turtles that express electro- or magneto sensitivity) that occur in the project area, existing information should likely be searched to determine the following:

- Population parameters (population status and trends, age and size structure)
- Seasonal, diurnal, annual distribution
- Migration paths—diurnal and seasonal
- Feeding locations/congregations
- Avoidance/attraction behaviors, including deviation.

This information could then be contrasted with EMF output of device components, if available, and propagation of those EMFs in important habitats (or model estimates of output).

In the specific case of the OPT Reedsport project site, local population parameters for some species may be known. Crabs and some salmon species occur commonly enough in the area to be measured. Distributions, migration timing, and paths may be known for some salmon, but it is important to distinguish between life history stages, which may show different patterns of movement and sensitivity to EMF. Feeding locations at the project site may be investigated. Existing information related to possible electric and magnetic fields in the area should be compiled. Finally, EMF emissions, pattern/duration of emissions, geometry, and field strengths of the PowerBuoy® system, if known, should be compiled.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for effects of EMF on receptors should be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Ocean Power Technologies Wave Energy project. As a general statement, however, EMF stressor thresholds for either detection by organisms or effect on organisms (e.g., change in behavior) are poorly understood, and protocols should ideally be developed to achieve useful thresholds and metrics for assessing them.

Scientific Thresholds

For species that could occur in project area, an important goal is to determine whether a significant proportion of the population is being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities or increase in migration distances and thus added energetic cost). This is particularly true for species with a small population size. Different life stages of species like salmonids may have different thresholds.

Evaluating whether significant changes in behavior—e.g., changes in migration routes or feeding locations will occur as a result of sensitivity to EMF—will require both baseline information on animal distributions as well as quantifying changes in these parameters in response to changes in EMF distribution. It is possible to use this field-generated information to develop ecological thresholds such as energetic (i.e., daily metabolic requirements, energy balance) as well as time-based thresholds and avoidance or attraction (similar to bird flight studies for offshore wind farms; see Speakman et al. 2009). Finally, if species are spawning in the area of the project site, or if very young (e.g., egg, larval) stages advect there, effects of EMF on embryonic development or larval/juvenile growth can serve as a threshold (see references in Normandeau et al. 2011).

It will be important to distinguish between detection levels and the levels to which receptors respond; few studies have looked at both detection and behavior (e.g., avoidance or attraction). There are some response level studies, and the recent BOEM EMF report (Normandeau et al. 2011) has tables with the most up-to-date information in terms of thresholds. Often studies do not encompass the full range of EMF, and often experimental studies will provide information only between two extremes—highest are avoidance, lowest are the detection—and from this it is difficult to identify specific thresholds. As noted above, there are no specific protocols for EMF work in terms of cable or generators like wave energy devices.

Regulatory Thresholds

Under the ESA, the take or injury of one individual or harassment by EMF represents a regulatory threshold; pertinent species include salmon, sturgeon, and sea turtles. The *Magnuson–Stevens Fisheries Conservation and Management Act* (MSFCMA) regulates take of fisheries species, including salmon, sturgeon, and sharks. Given our lack of knowledge of scientific thresholds, however, it is unclear how one would identify regulatory thresholds, what constitutes harassment, or even how harassment by EMF would be defined.

Step 6: Baseline Information Monitoring Needs

The focus here will be on unknown baseline information, expanding upon what information can be gathered from the literature, including diel, seasonal, and annual distribution of relevant species in the project area; feeding locations in project area; and a background survey of the existing EMF field, in the absence of wave energy devices (for estimates, see Chapter 2 in Slater et al. 2010). In addition to the spatial component, it is also important to measure seasonal variability of EMFs induced in the system by external geomagnetic/ionospheric (geomagnetic storm) activity.

For existing biological protocols, stock assessment techniques—using fisheries surveys—may be a default approach, but their effectiveness for EMF is questionable. Given the spatial and temporal scale of sampling needed, it would be difficult to determine whether EMF is for the cause of observed change; alternative protocols will likely need to be developed.

Step 7: Effects Monitoring Information Needs

Although the fields generated by wave energy devices can be estimated (Chapter 3 in Slater et al. 2010), the EMF emissions, pattern/duration of emissions, geometry and field strengths of the PowerBuoy® system will need to be measured when the equipment is installed as well.

Studies will be needed to evaluate effects of EMF on the species of interest; they may include continuing to monitor migration pathways and feeding behavior to detect avoidance/attraction behavior and monitor interactions. During these studies, if the pattern of emission is shown to be intermittent, it will change the properties of the stressor to the receptor; this may require simultaneous sampling of the stressor.

For EMF as a stressor, it will be difficult to find appropriate reference sites. It might be necessary to deploy a non-energized (dummy) cable at the reference site. Otherwise, it would be difficult to understand the behavior of the organisms in the reference area, particularly if it is suspected that physical aspects of the cable rather than EMF emissions are altering the behavior of marine biota. Laboratory or large tank experiments represent an alternative to reference sites and can potentially be conducted for the species of concern. Field studies such as those conducted by Gill et al. (2009) would be difficult to accomplish in the rigorous environment where wave energy devices would be used on the west coast of the United States.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

EMF Protocols

The best resource at the present time for EMF measurements pertinent to wave energy is the series of reports from the Oregon Wave Energy Trust (Slater et al. 2010). Protocols pertinent to baseline characterization include site assessment methodology (Chapter 4) and the prediction of these fields from the wave energy device (Chapter 3) if information on the EMF profiles of the OPT wave energy generator is not available, Biological Protocols

Stock assessment protocols developed for other purposes are applicable for estimating abundance.

Study Design for Baseline Monitoring EMF Dynamics

Design of baseline monitoring should take a phased approach. Slater et al. (2010, Chapter 8) showed that there is a paucity of ambient EMF information in Oregon's coastal waters but provided a range of expected values. An initial determination of the estimated ambient field strengths (Chapter 2) can be made, followed by measurements in the field. Chapter 4 provides an approach to data acquisition at the Reedsport site that is sufficiently flexible to be applicable to other sites.

Protocols That Need Development/Testing

Improved approaches to examining baseline migratory movements of species like sturgeon and salmonids should be developed. These may include tagging or video observation. Similarly, assessment of directed crab movements represents an analogous need.

Selecting a Protocol for Baseline Monitoring of EMF for the Ocean Power Technologies Wave Power Project

The protocols defined in Chapter 4 of Slater et al. (2010) provide an approach to data acquisition using the Reedsport site as an example. This can serve as the protocol for baseline monitoring.

Step 9: Effects Monitoring Protocols

Existing Protocols

EMF Protocols

For wave energy, the protocols covered in Slater et al. (2010) cover most of the approaches required, ranging from the instrumentation to estimating EMF signals of devices to the actual measurement. It is important that the instruments used are able to measure biologically meaningful levels of EMF. Additional techniques and protocols may be required for biological measurements.

Biological Protocols

Response level studies are summarized in Normandeau et al. (2011); the techniques used in these papers are appropriate to assess behavioral thresholds, but application to the field is challenging. Laboratory studies (e.g., Woodruff et al. 2011; Kimber et al. 2011) and field studies (e.g., Gill et al. 2009) can show effects and measure thresholds, allowing inference about how the target species might react to measured EMF at the project site. They are not, however, appropriate protocols to determine behavioral effects at the sites of specific wave energy projects, and those should be developed.

Protocols That Need Development/Testing

Biological Protocols

As noted above, for ESA-listed species (sturgeon, salmon, sea turtles), a regulatory threshold is harassment. Protocols will need to be developed for identifying harassment by EMF.

A problem with stock assessment protocols that they are only correlative and not definitive as it is not possible to detangle whether a change in fish abundance is a result of cable presence, some other attractant (e.g., FAD) or the EMF. Tracking studies are generally more scientifically effective and are more cost effective if well-designed. Tagging/tracking studies on larger geographic scales have been developed for salmonids (Welch et al. 2003) and green sturgeon (Lindley et al. 2008), and these techniques can be modified for smaller scales (and the needed higher resolution) to develop protocols to monitor the movements of fish and crabs within the project area in relation to EMF fields.

European research has examined the potential effect of EMF from cables on the migration of European eels (Westerberg and Lagenfelt 2008). Along the U.S. West Coast, research for measuring EMF along submarine cables as well as detecting aggregations of organisms along cables has been planned by BOEM's 2011–2013 studies plan (http://www.BOEM.gov/omm/pacific/enviro/2011-2013_Studies_plan.pdf) and is described as an ongoing study (http://www.BOEM.gov/omm/pacific/enviro/Enviro-Studies/PC-11-03.pdf).

Using submersible observations and existing techniques, the BOEM studies will determine distributions of fish along cables and reference sites. It is likely that this project will result in protocols appropriate to address stressor–receptor interactions, at least along cables.

5.5 NOISE/VIBRATION AND CETACEANS

Wave Energy High Priority Interaction #5

Reedsport, Oregon

Stressor: Noise/Vibration

Receptor: Cetaceans

Step 1: Description of Technology and Site/Location

This case study is based on wave energy technology deployed in Reedsport, Oregon. Detailed information on the project is included in the Technology and Site Characteristics section at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

High priority/high importance interactions were developed as described in Chapter 3. This example reviews the specific information below.

> **Stressor: Noise/Vibration Priority: High**
> Cetaceans could be harassed by noise generated by wave energy converters while migrating through and/or feeding in the area.

Step 3: Spatial and Temporal Scale of Stressor

For the Ocean Power Technologies wave energy case study, wave energy capture devices and the associated anchors and subsea cables may produce sound above ambient levels, representing the physical stressors that could affect cetaceans (receptor) in the project area. The three-dimensional footprint of the static device stressor is as follows:

- Array footprint for 10 buoys: 0.12 km^2 (30 ac.)
- Anchor area: 625 ft^2 each, 10,000 ft^2 total
- Distance between anchors: 100 m
- Array will be 1.3 km long in an east–west orientation × 1 km wide

The acoustic signature and sound propagation from the device need to be measured to determine the distances at which sound is detected or may harass cetaceans. There will also be variations in the magnitude of device-produced sound as a function of sea state.

The temporal scale or duration is constant, except for cessation of noise of moving components during shutdown or maintenance. Noise due to strumming or mooring lines or other interactions of the ocean with static components will remain present. It should also be noted that intensity of the produced sound will vary on a temporal basis.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

Preliminary assessment will largely be literature search based, using existing information. Examining spatial-temporal overlap between the sound field and marine mammals requires information on distribution of both. The first requires characterizing the sound field and understanding receptor distribution on a fine scale to address overlap. For each cetacean species that could occur in the project area, determine:

- Population parameters (population status and trends, age and size structure)
- Seasonal, diurnal, annual distribution
- Migration paths (depth/distance from shore)
- Feeding locations
- Avoidance/attraction behaviors
- Auditory range
- Noise level and frequency of device components (if available)

The best sources for distributional data of ESA-listed and MMPA-protected species are found in Barlow et al. (2009, 2010) and Forney (2007). ESA-listed species of cetacean potentially present in the project area include humpback, blue, fin, sei, sperm, and Southern Resident killer whale. Although the ESA-listed species have not been observed in the project area, distributional studies suggest that some may occur there. Southern Resident killer whale have been observed south of the project area in winter, and it is likely that they may pass through this nearshore area of the OPT project. In summer 2011, humpback and blue whales were observed as close as 3 mi offshore of Newport and Depoe Bay (Lagerquist, pers. comm.), so it is likely that similar patterns may be seen off Reedsport.

MMPA-protected species of cetacean that have been observed in the project area include gray, minke, and killer whales; harbor and Dall’s porpoise; northern right whale dolphin; Pacific white-sided dolphin; Risso’s dolphin, and short-beaked common dolphin. Although gray whale migration tracks have not been identified off Reedsport, it is not unlikely that they would be similar in terms to distance offshore and seasonality to those off Newport (Ortega-Ortiz and Mate 2008). Minke whales, northern right whale dolphin, Pacific white-sided dolphin, Risso’s dolphin, and short-beaked common dolphin tend to be farther offshore so may only potentially occur in the project area.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for changes to cetaceans would be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Ocean Power Technologies Wave Energy project.

Scientific Thresholds

Baseline and effects monitoring should ideally assess the acoustic emissions of the PowerBuoy® system relative to background/ambient sound and to hearing for species of interest, and then detect if the scientific thresholds are exceeded for marine mammals in the project area.

For example, for species that could occur in the project area, if a significant proportion of population is affected indirectly by alterations in behavior (e.g., avoidance of area resulting in loss of feeding opportunities or increase in migration distances), scientific thresholds could be exceeded. This research area, however, is plagued by a very great deal of uncertainty. The sound power level is not the only issue, but there are very important issues of frequency, which may differ among species; delphinid frequency bands are very different from those of larger whales (Southall et al. 2007). In addition, the nature of the sound (fluctuation, directionality) is important; some species respond to certain types of sounds more than others, even for sounds in the same frequency band. There are also differences between the detection thresholds and the response thresholds, and these are not available for all species. Research on this topic has included work on developing acoustic devices to promote cetacean avoidance of certain areas (Barlow and Cameron 2003). These issues have been summarized for offshore wind energy by Madsen et al. (2006).

Regulatory Thresholds

The official regulatory thresholds are as follows:

Under the ESA, the take or injury of one individual or harassment by presence of devices or traffic to devices represents one threshold. Specific harassment by acoustics identifies two sound levels. The first is the level that may cause injury (Level A,>180dB); the second is the level that may cause harassment (Level B,>120 dB for continuous noise and >160dB for pulsed noise). Under the MMPA, harassment due to noise can be considered take if sufficient injury is inflicted (Level A) or a change in behavior is caused (Level B).

A great deal depends upon the interpretation of the legislation by NOAA's Office of Protected Resources. Technically, if the noise is above the detection threshold, the *potential* for behavioral changes exists. Under current interpretation of the MMPA/ESA, such a *potential* may be sufficient to require permits. For a more specific answer to questions (especially if endangered species are in the area of interest), it is useful to consult with the NOAA Office of Protected Resources at http://www.nmfs.noaa.gov/pr/permits/mmpa_permits.htm.

In reality, scientific thresholds do not exist, as noted above, because the research has not been done. The 120-dB figure for harassment has been used for a long time but is based upon gray whales off the West Coast (with criterion being diversion of migratory patterns). The application as a regulatory threshold is because it represents all the information historically available. Because of their size and ability to train in captivity, detection limits for sound in some species of dolphin are known, but not necessarily response thresholds.

NOAA NMFS is in the process of dividing marine mammals into five "functional hearing groups" as relates to sound (following Southall et al. 2007); these are pinnipeds in water, pinnipeds in air, low-frequency cetaceans (baleen whales), mid-frequency cetaceans (most dolphins, small whales), and high-frequency cetaceans (porpoises and some dolphins). These will be separated by frequency bands and also grouped by acoustic stressors.

Step 6: Baseline Information Monitoring Needs

The key information needs on interactions between cetaceans and acoustics/noise from the devices will require 1) pre-deployment acoustic characterization of the project site to determine background acoustic conditions on diurnal, seasonal, and storm scales; 2) diurnal, seasonal, and annual distribution and abundance patterns of cetaceans in the study area; 3) feeding areas, if present, in the project site; and 4) sound propagation modeling specific to the physical conditions of the project site. For species like gray whales with known migratory pathways, fine-scale movement patterns like those determined by Ortega-Ortiz and Mate (2008) will need to be determined.

Step 7: Effects Monitoring Information Needs

Studies will be needed to evaluate the effects of acoustics and noise on cetaceans. These will include both acoustic and biological measurements. First, acoustic emissions of the device and associated mooring systems will need to be measured to determine the sound signature and its relationship to background conditions. This work will need to be conducted in a variety of wave heights and sea states. The field of influence of sound is determined through knowledge of the sound source and sound propagation modeling (Erbe and Farmer 2000) to assess the level of sound received by the animal of interest; the model developed during baseline sampling will need to be evaluated during the effects stage. Biological sampling will require continued monitoring of migration pathways and feeding behavior to detect avoidance/attraction behavior and monitoring interactions that may be specifically related to sound.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

Acoustic

Measurement of background noise needs to be conducted using calibrated hydrophones to ensure intercalibration with other studies and instruments. Although no explicit protocols exist for requisite frequencies and instruments, recent research on this topic has been summarized by Madsen et al. (2006). Acceptable protocols for sound measurement for ocean renewable energy should be refined for both baseline and effect studies. Sound propagation modeling is well developed. Appropriate protocols include those in Erbe and Farmer (2000).

Biological

Ortega-Ortiz and Lagerquist (2009) identified the basic existing protocols available for monitoring cetaceans in the vicinity of wave energy devices. To collect baseline information about marine mammals that may occur in the vicinity of the OPT study site, the following monitoring protocols can be used to determine the diurnal, seasonal, and annual variability in marine mammal distribution and habitat use.

- *Visual approaches*: Although a variety of published studies (e.g., Barlow et al, 2009, 2010) have used boat-based studies or aerial surveys, these are expensive, time consuming, and weather dependent and may not be of appropriate scale for the smaller nearshore areas where wave energy devices will be deployed. Ortega-Ortiz and Mate (2008) used shore-based theodolite tracking, successfully defining tracks of the different migration groups moving along the coast. Ortega-Ortiz and Lagerquist (2009) concluded that this was the best approach for large whales.

- *Passive Acoustic Monitoring*: Passively sensing the acoustic emissions from marine mammals can be used to identify presence/absence and also patterns of abundance. It is the best technique for odontocetes but may not be useful for gray whales, which vocalize less during migration and feeding. Various devices are available to conduct such work at the high frequencies used by marine mammals and typically target 100–150 kHz for harbor porpoise and up to 60 kHz for dolphins. Standards for marine mammal work generally use continuous recording of low-frequency sound and intermittent recording of high-frequency sound (due to storage and battery limitations). Sampling should ideally be done on diel, seasonal, and storm temporal scales (Mellinger et al. 2007).

Study Design for Baseline Monitoring Cetaceans and Acoustics for the Ocean Power Technologies Wave Power Project

The acoustic sampling and sound propagation modeling should follow accepted approaches in the literature (e.g., Madsen, et al. 2006; Erbe and Farmer 2000) until a formal protocol has been developed.

For biological sampling, migrating whales in the OPT project area should be well within range of shore-based theodolite sampling; the techniques of Ortega-Ortiz and Mate (2008) should ideally be conducted during the northward and southward migratory season for 1 year prior to the OPT deployments, to address gray whale distribution and to observe any other large whales present along with their movement patterns. Passive acoustic monitoring following the approach of Mellinger et al. (2007) could also be conducted during the year prior to deployment to determine other species of cetacean present in the area of deployment.

Protocols That Need Development/Testing

Acoustic

Although a variety of studies have conducted assessments of background noise and vibration in marine systems, there is a need to develop a specific protocol pertinent to marine renewable energy installations; baseline studies have recently been developed for wave facilities (Haxel et al. in press). The protocol should be tailored to both address the frequencies that have biological importance (i.e., for marine mammals, fishes) and to encompass the range of frequencies likely to be generated by wave energy devices. The methods of recording will likely vary by frequency due to the battery and storage requirements associated with high frequencies.

Biological

The baseline protocols above are well developed, but several additional tools could be further developed to address needs for effects monitoring. One approach is with telemetry. Tagging with satellite, acoustic, or other “smart” tags can be useful to provide results but have several drawbacks. Tags can be deployed on only a small percentage of the population, and there is no guarantee that the tagged animals will visit the vicinity of the project site. Monitoring tracks of gray whales with the resolution required will need the accuracy of quick-fix GPS tags, which must be recovered to get the data. Other tags, such as acoustic transponders with receivers affixed to the wave energy devices, are also possible and could serve a dual purpose to detect salmonids, sturgeon, and other fishes and mobile marine organisms.

Selecting a Protocol for Baseline Monitoring of Cetaceans and Acoustics for the Ocean Power Technologies Wave Power Project

The protocols noted above under Study Design are those currently available for use that will yield useful results.

Step 9: Effects Monitoring Protocols

Existing Protocols

To assess the potential effect of acoustic emissions of wave energy projects on marine mammals, it will be necessary to have the data from baseline monitoring to determine the distribution, abundance, migratory pathways, and habitat use of marine mammals as well as the background acoustic noise from predeployment sampling. In general, effects monitoring protocols will be the same as baseline protocols for determining acoustic emissions of the devices over background and the propagation of that sound will also need to be determined via testing the models developed during the baseline stage. The protocols to assess the distributions, migration tracks, and feeding behavior of cetaceans will likewise be similar to those in the baseline measurements, but the need to statistically detect change in the parameters from the baseline study will add a dimension for which no clear protocols are available. Frankel (2005), for example, was able to detect altered movement patterns in gray whale confronted with a sound signal by using two adjacent shore-based theodolite samplings to extend the range of detection; extension and improved development of this technique may be useful for detecting change (i.e., may be a candidate for additional protocol development).

Protocols That Need Development/Testing

As noted above, telemetry approaches like those for monitoring may be useful. In addition, scanning sonar systems that could be mounted to wave devices and identify marine mammal targets would also be possible to assist in determining behavior. Direct video observation of fine-scale behavior around devices is possible using critter-cams (Williams et al. 2000) mounted on species shown to be attracted to the devices may demonstrate interaction with devices. Finally, using multiple recording hydrophones and sound propagation modeling may be possible to estimate locations of marine mammals (Tieman et al. 2004). None of these approaches are sufficiently well developed to use at this time and will require research before being implemented to use around wave energy devices. Fallback sampling for smaller marine mammals could include boat and aerial surveys, should these techniques fail to develop.

Perhaps the most important critical protocol needed for this area is that of effects monitoring for acoustic harassment. If the sound generated by the devices exceeds that of the regulatory thresholds, then there is no accepted protocol to determine whether animals are in fact being harassed.

6 TIDAL ENERGY CASE STUDIES

AUTHORED BY PACIFIC NORTHWEST NATIONAL LABORATORY

DISCLAIMER: *The companies referenced in this section were not involved in developing content, analysis, or conclusions. The project information presented in this report is based on the project team's summary of existing public information available at the time of its drafting, and is not endorsed by any company to be representative of any current or planned project.*

Step 1: Description of Technology and Site/Location

The case study chosen for tidal power is a commercial-scale project in Admiralty Inlet, Puget Sound, Washington, consisting of 20 to 40 turbines (Figure 6-1). The technology chosen is an open center turbine, developed by OpenHydro, each 10 m in diameter, intended to be deployed at a depth of approximately 50 to 60 m. Each turbine deployed will be held in place by a gravity tri-frame, with tubular cans directly contacting the seafloor at the vertices, creating a foundational footprint of approximately 10 m^2. The hub height of each turbine is 10 m above the seabed with a 40-m overhead clearance to the water surface (at lowest astronomical tide). The turbines will be approximately 30–40m apart from each other connected by 1 to 2km of 117-mm trunk subsea cable carrying alternating current (AC). Structurally, the OpenHydro turbines are fixed-pitch, high-solidity rotors with an open center. A permanent magnet generator is contained in a shroud around the blade perimeter. The rotor cassette is the single moving part and rotates within the shroud on water-lubricated bearings. The turbines are connected together in groups by undersea cables that then connect to one or more independent power and communications cables to shore. The cables are laid on the seabed and held in place by their own mass until entering a horizontally directionally drilled duct around the 20-m isobaths and run to facilities located on shore. The dimensions of the commercial-scale tidal project are extrapolated from a proposed pilot-scale project to be developed in the area (Polagye et al. 2011).

Figure 6-1. Open Hydro Turbine and Project Map. Left: Schematic of an open-center OpenHydro turbine. Right: Map of Puget Sound, Washington, with commercial tidal project site in Admiralty Inlet denoted by red box.

Physically, Admiralty Inlet is a constricted sill separating the deep Main Basin of Puget Sound from the straits of Juan de Fuca and Georgia. At the narrowest point, between Admiralty Head and Point Wilson, the channel is approximately 5 km wide and 60 m deep. Except for a small exchange through Deception Pass, the entire tidal prism of Puget Sound passes through this constriction, giving rise to tidal currents that routinely exceed 3 m/s (6 knots). The project site is located off Admiralty Head in 50 to 60 m of water. The location was selected due to strong tidal currents (intensified by the proximity to the headland), negligible seabed slope (necessary to optimally deploy a gravity foundation), separation from high vessel traffic areas (federal navigation lanes, ferry route), and ease of cable routing back to shore (Polagye et al. 2011).

Admiralty Inlet is the main ingress/egress for biological populations, commercial shipping, and other vessel traffic into and out of Puget Sound. The biological environment around the tidal power project area is not well understood because the high flow environment in Admiralty Inlet creates a difficult environment for oceanographic measurements and biological assessments. Numerous marine mammals inhabit the area; some of the more notable ones are the harbor porpoise and the endangered Southern Resident killer whale (SRKW). Several resident and migratory fish populations, including stocks of endangered Pacific salmon and rockfish, also utilize the area (Palsson et al. 2009; Caretta et al. 2011).

Sediment along the seabed consists primarily of cobbles/boulders as well as crushed shell and gravel (Polagye et al. 2011). Most of the cobble area is colonized by barnacles, sponges, and algae. The water column is well mixed, with a considerable amount of biological detritus at depth. Because there is a high level of commercial vessel traffic, noise levels are relatively high, averaging at 117 dB re 1 µPa and range from 100dB to 140dB (Bassett et al. submitted). The movement of gravel and shells from the strong currents also generates noise at frequencies from 4 to 50 kHz (Polagye, B. 2011. pers. comm.).

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

Step 2: Identify Priority Stressor-Receptor Interaction

Environmental interactions can be evaluated from several different perspectives. The project team conducted the following evaluations: 1) expert opinion, 2) regulatory, and 3) stakeholder values. This approach ensured that each interaction was viewed from the different and relevant perspectives that are known to have a major influence on the siting, licensing, and permitting process for commercial-scale ocean renewable energy projects. The expert opinion, regulatory, and stakeholder values evaluations were combined for an integrative analysis. Criteria were developed to determine protocol development priorities. The integrated list is outlined in Table 6-1.

Table 6-1 Tidal energy – summary matrices (see Section 3 for a summary of how these priorities were developed).

A. Moving Devices			
	Expert Opinion	Regulatory	Stakeholder Values
Ecosystem Interactions	🟨	🟨	⬜
Resident Fishes	🟨	🟨	🟥
Migratory Fishes	🟨	🟨	🟥
Elasmobranchs	🟨	🟩	⬜
Cetaceans	🟥	🟥	🟥
Pinnipeds	🟥	🟥	⬜
Birds	🟩	🟨	🟨
B. Noise and Vibration			
	Expert Opinion	Regulatory	Stakeholder Values
Resident Fishes	🟩	🟨	🟥
Migratory Fishes	🟩	🟨	🟥
Cetaceans	🟥	🟥	🟥
Pinnipeds	🟨	🟨	⬜
Birds	🟨	🟨	⬜
C. EMF			
	Expert Opinion	Regulatory	Stakeholder Values
Benthic Invertebrates	🟨	🟩	⬜
Resident Fishes	🟨	🟩	🟨
Migratory Fishes	🟨	🟥	🟨
Elasmobranchs	🟥	🟩	🟨
D. Static Devices			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics	🟨	🟩	⬜
Water Circulation	🟨	🟩	⬜
Water Chemistry	🟨	🟩	⬜
Nearfield Habitat	🟨	🟨	🟨
Benthic Invertebrates	🟨	🟩	⬜
Resident Fishes	🟨	🟩	🟥
Migratory Fishes	🟩	🟩	🟥
Cetaceans	🟩	🟥	🟥
E. Energy Removal			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics	🟨	🟨	🟥
Water Circulation	🟨	🟩	🟥
Water Chemistry	🟨	🟥	⬜
Ecosystem Interactions	🟨	🟨	⬜

Table 6-1 Tidal energy – summary matrices (continued).

F. Chemical Release			
	Expert Opinion	Regulatory	Stakeholder Values
Sediment Characteristics		🟩	🟥
G. Boat Traffic			
H. Lights			

The complete list of high- and medium-priority interactions for wave energy is identified in Chapter 3. Listed below are the interactions selected for case studies:

- *Moving devices and cetaceans and pinnipeds.* Cetaceans and pinnipeds may potentially swim into rotating blades, by accident or out of curiosity.
- *Noise/vibration and cetaceans.* Acoustic output from rotating blades may disrupt cetacean communication and navigation.
- *EMF and elasmobranchs.* Changes to electromagnetic fields may affect elasmobranch behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey.
- *Moving devices and fishes.* Rotating turbine blades could present risk to resident fish, migratory strike, and/or sharks from strike (adults), entrainment or impingement (eggs, larvae, juveniles). High degree of uncertainty.
- *Energy removal and sediment characteristics and water chemistry.* Changes in circulation due to energy removal could cause changes in water chemistry and farfield changes in sediment patterns in low energy areas and nearshore.

6.1 MOVING DEVICES, CETACEANS AND PINNIPEDS

Tidal Energy High Priority Interaction #1

Admiralty Inlet – Puget Sound, Washington

Stressor: Moving Devices

Receptor: Marine Mammals – Cetaceans and Pinnipeds

Step 1: Description of Technology and Site/Location

This case is based on tidal energy technology deployed in Puget Sound, Washington. A detailed description of the geophysical location and technology used is provided in the Technology and Site Characteristics description at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

High-priority interactions were developed through a process of identifying the high-consequence stressor–receptor interactions. This example reviews the specific information below.

Stressor: Moving Devices **Priority: High**
Issue: Cetaceans and pinnipeds may potentially swim into rotating blades, by accident or out of curiosity.

Step 3: Spatial and Temporal Scale of Stressor

For the Admiralty Inlet tidal power case study, the device frame and rotating turbine blades (stressors) may potentially harm marine mammals (receptors) in the project area if they come into physical contact with the blades. Spatially, the physical dimensions of the stressor are as follows:

- Shroud diameter: 10m (rotor diameter ~8)
- Overall height: 15 m (seabed to top of shroud)
- Depth: 50–60m
- Overhead clearance to water surface: 40m (at lowest astronomical tide)
- Distance between each tidal turbine: 30–40m
- Footprint for individual turbine: 10m2
- Footprint depth below seafloor: <10m2
- Total footprint of project: 2–4km2
- Maximum rotational speed: between 15 and 20 rpm.

Temporally, the scale chosen for the interaction of turbine blades with marine mammals includes the amount of time that the turbine blades are rotating in a tidal cycle and the operational profile of the spinning blades. It is thought that the tidal turbines will be operating on average 68% of the time, or for roughly 16.3 hr in a 24-hr period. Contributing factors include cut-in speed, tidal current speeds through the annual tidal cycle, and asymmetry of tidal currents in the project area.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to analyze how the OpenHydro tidal turbine blades (stressor) affect marine mammals (receptors) within the project vicinity, a thorough understanding of the baseline conditions within the project area are needed. To achieve this, spatial distribution and behavioral data are needed for marine mammal populations of concern, including measures of: population distribution, age structure, and reproductive rates; seasonal and diurnal patterns of movement through the study area; behavior during diving, feeding, resting, and other common activities in study area; and auditory range of species and their ability to detect the acoustic output created by the spinning turbines over the tidal cycle.

Marine mammals of particular importance are the SRKW due to their protected status under the ESA. Harbor porpoises, gray whales, minke whales, Dall’s porpoise, Steller sea lions, and harbor seals can also be seen near the project area.

Recognizing the financial costs and scientific challenges in obtaining all of the population and behavioral information for all marine mammals in the project area, baseline studies should focus on harbor seals and harbor porpoise because of their abundance in the region.

The preliminary assessment of overlap between the tidal turbine blades and marine mammals should also include assessment of the location and operational profile of the OpenHydro turbines in Admiralty Inlet. Information needs include the number of hours the blades spin per tidal cycle and the probability distribution of rotational rates (revolutions per minute).

Step 5: Scientific and Regulatory Thresholds

Protocols used for post-installation monitoring of marine mammal interactions with tidal turbine blades should be designed to detect changes that exceed the following scientific and regulatory thresholds, as a result of the installation and operation of the tidal power project.

Scientific Thresholds

Baseline and effects monitoring protocols for marine mammals must be able to detect the following scientific thresholds:

1. Direct (strike) or indirect (avoidance) interaction with turbine blades, causing or contributing to the death, injury, or incapacitation of individual mammals that results in population decline of the species; or
2. For critically small populations, direct (strike) or indirect (avoidance) interactions with turbine blades, causing or contributing to the death or incapacitation of individual mammals that threatens the stability or reproductive success of the population. Critically small populations in the project area include the SRKW.

Regulatory Thresholds

1. For marine mammals listed under the ESA, the regulatory threshold is the “taking” of one individual. Any harassment, injury, or mortality to a protected species is a “take” under the ESA. In the tidal case study area, ESA-listed species include SRKW and Steller sea lions.
2. All marine mammals in U.S. waters are protected under the MMPA. The MMPA prohibits, with certain exceptions, the “take” of all marine mammals. To harass or kill an individual marine mammal is considered a “take” under the MMPA. The act, however, allows the National Marine Fisheries Service (NMFS) to grant “incidental take authorizations” (or “Letter of Authorization”) to nonfishing maritime activities, if it is determined that the takings will be of small numbers and have no more than a “negligible impact” on a marine mammal species that is not listed as depleted under the MMPA. Listed species in the case study area include the SRKW and Steller sea lions. As such, the taking of one SRKW or Steller sea lion exceeds the regulatory threshold of the MMPA. For other marine mammals in the region, including transient killer whales, gray whales, minke whales, harbor porpoise, Dall’s porpoise, Steller sea lions, and harbor seals, the regulatory threshold is subject to the Letter of Authorization granted to the project by NMFS.

Step 6: Baseline Information Monitoring Needs

Although marine mammal behaviors and spatial distributions have been studied in many different environments (Tollit et al. 2011; ICES 2011; Matthiopoulos and Aarts 2010), little is known about the detailed behavior of marine mammals in Puget Sound, including SRKW, harbor porpoises, Dall’s porpoises, and Steller sea lions. Detailed behavioral information on the cetacean and pinniped species in the region and their spatial distribution (latitude, longitude, and depth distribution) is largely unknown. With the exception of SRKW, current population size, age structure, and reproductive rates are largely unknown for cetaceans and pinnipeds in Puget Sound. Constructing a behavioral model of the marine mammals thought to be at risk is needed prior to turbine deployment to understand the natural swimming, diving, resting, and socializing behavior of the animals.

The operational profile of OpenHydro turbines in Admiralty Inlet needs to be determined, to understand the mechanisms that might provide a risk of strike or behavioral change to marine mammals.

Step 7: Effects Monitoring Information Needs

To evaluate the effects of potential interactions between marine mammals and rotating turbine blades, the behavioral models of marine mammal species developed through baseline studies should be evaluated to determine whether there is significant overlap in species distribution and movement patterns with the tidal turbines (horizontally and vertically). Post-installation monitoring of the presence of marine mammals in the vicinity in the turbines using direct observations or surrogate measures can also be used to evaluate the effects of interactions between marine mammals and rotating turbine blades.

Because before–after-control–impact (or BACI) designs are favored for assessing impacts (Macleod et al. 2010), it is generally recommended that effects monitoring studies include a control reference site with similar physical/biological characteristics. For the tidal case study, no reasonable control reference site for Admiralty Inlet has been found in Puget Sound or the Salish Sea region. In the absence of control sites, ensuring good baseline monitoring of marine mammal populations is essential pre-installation for comparison to post-installation.

Step 8: Baseline Monitoring Protocols

Existing Protocols

A variety of observational and satellite tagging methods can be used for baseline monitoring protocols of marine mammals in the tidal project area, including observational techniques such as line transect sampling, fixed-point surveys, and aerial sighting surveys (Macleod et al. 2010; Hammond 2010). Although these strategies can provide information on marine mammal distributions, these observation methods may generate a large amount of variability in the data and can be fairly time consuming. Satellite tagging, telemetry, and hydroacoustic monitoring can also be used to assess the population census of various marine mammals and can provide data with high spatial and temporal resolution (Macleod et al. 2010; Mathiopoulos and Aarts 2010; Tollit et al. 2011). Table 6-2 summarizes some of the advantages and disadvantages of the monitoring techniques.

Protocols That Need Development/Testing

Additional protocol development for baseline monitoring should focus on developing a behavior model of the marine mammals that may be present in Admiralty Inlet, as the animals are likely to interact with the tidal turbines.

Table 6-2 Advantages and disadvantages of monitoring techniques for baseline monitoring of marine mammals (Macleod et al. 2010).

Technique	Advantages	Disadvantages
Line Transect Surveys	• Data allow for estimation of absolute or relative density and abundance • Can provide information on distribution • Can cover entire range of population	• Often expensive • Restricted by weather conditions and to daylight hours • Variability often high- can be difficult to detect trends
Aerial Surveys	• Can cover large areas quickly • Can take advantage more readily of good weather windows • May already be taking place to carry out bird surveys	• Logistical limitations • Responsive movement may be a problem for some aircraft types or some species

Table 6-2 Advantages and disadvantages of monitoring techniques for baseline monitoring of marine mammals (Macleod et al. 2010) (continued).

Fixed Point Surveys	• Inexpensive • Observers not influencing behavior of animals • Can provide spatial and temporal data on habitat usage and distribution • Can be extended to assess long-term trends	• Generally not possible to estimate abundance • Experienced observers are required • Weather restricted • Need to find a suitable site/vantage point • Often confined to coastal strips or channels
Telemetry	• Can provide information on movements, migration and range of individuals, and behavior • Can provide information on habitat preferences and areas of special importance • Detailed information on animals without human disturbance	• Many individuals need to be tagged to make general conclusions • Invasive-potential welfare issues from tagging process • Equipment and tagging process is relatively expensive
Hydroacoustics	• Data are independent of daylight and most weather conditions. • Can provide high spatial and/or temporal resolution • Data collection can be relatively inexpensive • Long term data sets can be collected	• Methods to estimate abundance are not well developed • High frequency vocalizations have a limited detection range

Step 9: Effects Monitoring Protocols

Existing Protocols

Although protocols have been developed to examine how the installation of tidal power projects in Europe affect marine mammals (Tollit et al. 2011), there are currently no post-installation protocols to monitor the effects of operating tidal turbines on marine mammals.

Protocols That Need Development/Testing

Improved observation and tagging protocols for all marine mammals within the study area should be developed to assess the animals' movements in and around the study area. Acoustic and optical techniques are promising for observing marine mammals interacting with turbine blades. Additional protocols are needed to take advantage of the ability of stress gauges on blades that register collision with objects over a specified weight to assist with determining whether marine mammals have been struck by turbine blades. Additional models that describe potential interactions of marine mammals with tidal turbine blades are needed to help design and evaluate field measurements of marine mammal approaches and interactions with tidal turbine blades.

6.2 NOISE/VIBRATION AND CETACEANS

Tidal Energy High Priority Interaction #2

Admiralty Inlet – Puget Sound, Washington

Stressor: Noise and Vibration

Receptor: Cetaceans

Step 1: Description of Technology and Site/Location

This case is based on tidal energy technology deployed in Puget Sound, Washington. A detailed description of the geophysical location and technology used is provided in the Technology and Site Characteristics description at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

High-priority interactions were developed through a process of identifying the high-consequence stressor–receptor interactions. This example reviews the specific information below.

Stressor: Noise and Vibrations **Priority: High**
Issue: Acoustic output from rotating blades may disrupt cetacean communication and navigation.

Step 3: Spatial and Temporal Scale of Stressor

For the Admiralty Inlet tidal power case study, the noise produced by rotating turbine blades is a potential stressor that can affect marine mammals within proximity to the device (receptors). The physical dimensions of the OpenHydro Turbine in Admiralty Inlet are as follows:

- Maximum rotational speed: between 15 and 20 rpm
- Average ambient noise level is 117 dB re 1 µPa
- Ambient noise range is 100 dB to 140 dB

The temporal scale of this stressor can vary with respect to the time of year and tidal velocity (spring vs. neap tides) in Admiralty Inlet. Over a 24-hr period, it is thought that the tidal turbines will be operating on average 68% of the time, or for roughly 16.3 hr. The acoustic output is also likely to vary with inflow current velocity or, possibly, with aging of the turbine components.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to analyze how the OpenHydro tidal turbines (stressor) affect marine mammals (receptors) within the project vicinity, a thorough understanding of the baseline conditions within the project area is likely needed. To achieve this, distribution and behavioral data are needed for marine mammal populations of concern, including measures of population distribution, age structure, and reproductive rates; seasonal and diurnal patterns of movement through the study area; behavior during diving, feeding, resting, and other common activities in the study area;

auditory range of species (both frequency and amplitude); existing ambient noise; potential for habituation of resident marine mammals to noise of similar frequent and intensity; profile of the acoustic output created by the spinning turbines over the tidal cycle; and directionality of turbine noise.

Marine mammals of particular importance are the SRKW due to their protected status under the ESA. Harbor porpoises, gray whales, minke whales, Dall's porpoise, Steller sea lions, and harbor seals can also be seen near the project area and should also be included in the assessment of the effects of noise from the tidal turbines (Carretta et al. 2011).

Step 5: Scientific and Regulatory Thresholds

Protocols used for post-installation monitoring for acoustic effects on marine mammals should ideally be able to detect changes in behavior at the individual and population level that exceed the following scientific and regulatory thresholds, as a result of the installation and operation of the tidal power project.

Scientific Thresholds

The sensitivity of baseline and effects monitoring protocols for marine mammals should be able to detect failure to remain below two scientific thresholds:

1. Noise and acoustic output generated by tidal turbine blades, causing or contributing to the death or injury of individual mammals that results in population decline; or
2. For critically small populations, noise or acoustic output generated by tidal turbines, causing or contributing to the death of individual mammals that threatens the stability or reproductive success of the population. Critically small populations in the project area include the SRKW.

Regulatory Thresholds

The sensitivity of baseline and effects monitoring protocols for marine mammals must be able to detect failure to remain below two regulatory thresholds:

1. For marine mammals listed under the ESA, the regulatory threshold is the "taking" of one individual. Any harassment, injury, or mortality to a protected species is a "take" under the ESA; regulators define harassment acoustics (Level A and Level B Harassment) for marine mammals as follows:
    a. Cetaceans
        i. Level A: 180 dB
        ii. Level B: 160 dB for impulse sounds; 120 dB for continuous noise
    b. Pinnipeds
        i. Level A: 190 dB
        ii. Level B: 160 dB for impulse sounds; 120 dB for continuous noise (Southall et al. 2007; NOAA 2011)

2. All marine mammals in U.S. waters are protected under the MMPA. The MMPA prohibits, with certain exceptions, the "take" of all marine mammals. To harass or kill an individual marine mammal is considered a "take" under the MMPA. The act, however, allows the National Marine Fisheries Service (NMFS) to grant "incidental take authorizations" (or "Letter of Authorization") to nonfishing maritime activities, if it is determined that the takings will be of small numbers and have no more than a "negligible impact" on a marine mammal species that is not listed as depleted under the MMPA. Listed species in the case study area include the SRKW and Steller sea lions. As such, the taking of one SRKW or Steller sea lion exceeds the regulatory threshold of the MMPA. For other marine mammals in the region, including transient killer whales, gray whales, minke whales, harbor porpoise, Dall's porpoise, Steller sea lions, and harbor seals, the regulatory threshold is subject to the Letter of Authorization granted to the project by NMFS.

Step 6: Baseline Information Monitoring Needs

Although marine mammal behaviors and spatial distributions have been studied in many different environments (Tollit et al. 2011; ICES 2011; Matthiopoulos and Aarts 2010), little is known about the detailed behavior of marine mammals in Puget Sound, including SRKW, harbor porpoises, and Dall's porpoises. In addition, an acoustic profile of the tidal turbines and the acoustic sound budget for Admiralty Inlet will need to be developed to understand the full suite of noise to which marine mammals will be exposed in the project area. Acoustic data for Admiralty Inlet are summarized in Bassett et al. (2012).

Step 7: Effects Monitoring Information Needs

To evaluate the effects of noise and vibrations on marine mammals, a model predicting the interaction of the turbine noise field with ambient noise and the auditory capabilities of the marine mammals inhabiting the area could be created. Behavioral responses of marine mammals to turbine noise should also be evaluated in order to gauge potential effects of tidal turbine noise and acoustic output, bearing in mind that a simple relation between received levels of noise and behavioral response is not indicated (Southall et al. 2007; Ellison et al. 2011). Although there are no suitable reference sites in Puget Sound or in nearby estuaries, these studies should ideally be conducted at a reference site with similar biological and physical characteristics.

Step 8: Baseline Monitoring Protocols

Existing Protocols

To collect baseline data on marine mammals in areas similar to the tidal power project area, observation techniques such as line transect sampling, fixed-point surveys, and aerial surveys are used (Macleod et al. 2010; Hammond 2010). Although these strategies can cover an entire range of a population, these observation methods may generate a large amount of variability in the data and are labor intensive. Satellite tagging, telemetry, and hydroacoustic monitoring are also used to examine the population census of various marine mammals, providing data with high spatial and temporal resolution (Macleod et al. 2010; Mathiopoulos and Aarts 2010; Tollit et al. 2011; ICES 2011). Table 6-2 describes the advantages and disadvantages of these techniques.

Investigators in Europe have developed a ‘Drifting Ears’ technology to measure baseline levels of ambient noise in tidal power project areas and the noise generated by tidal turbines (Wilson and Carter 2008).

Please see Table 6-2-: Advantages and disadvantages of monitoring techniques for baseline monitoring of marine mammals (Macleod et al. 2010), provided in section 6.1 of this chapter.

Protocols That Need Development/Testing

Adequate protocols exist to assess populations of cetaceans in Admiralty Inlet (see Step 8 above). Study methods have been developed to characterize the underwater ambient noise within Admiralty Inlet (Bassett et al. 2010). However, protocols should be developed to measure the acoustic and noise output generated by the tidal turbines, perhaps starting with the “Drifting Ears” technique (Wilson and Carter 2008).

Step 9: Effects Monitoring Protocols

Existing Protocols

Existing baseline protocols for measuring behavioral effects of stressors including noise on marine mammals will be useful for measuring effects of tidal turbine acoustics, including acoustic surveys, telemetry, aerial surveys, and fixed point surveys (Macleod et al. 2010; ICES 2011; Mathiopoulos and Aarts 2010; Hammond 2010; Tollit et al. 2011). Methods have been developed to identify criteria for injury from underwater sound levels (Southall et al. 2007) that will be applicable to modeling of sound exposure of marine mammals and to the design of post-installation monitoring design; although, as noted in Ellison et al. (2011) a dose–response framework may be inappropriate for assessing the behavioral response to lower intensity sounds. Acoustic measurement methods have been created to measure the noise and acoustic output generated by tidal turbines (Wilson and Carter 2007).

Protocols That Need Development/Testing

Protocols used to examine marine mammal behavior should be integrated with those for measuring the acoustic output of tidal turbines in order to evaluate the effects from the devices. Models that define the acoustic field in the area of the tidal turbines will play a role in interpreting outcomes of field measurements. Improved observation and tagging protocols should ideally be developed for all the marine mammals found within the tidal power project area (SRKW, harbor porpoise, harbor seals, gray whales, minke whales, and Dall’s porpoise) to gain a better understanding of how the generated noise and acoustics affects the behavior of these marine mammals. Baseline acoustic monitoring methods have been developed for other tidal projects (Wilson and Carter 2007); however, these protocols will require modification to fully assess the noise generated by the tidal turbines, how these noises differentiate from ambient noise, and their effect on marine mammals found in Admiralty Inlet.

6.3 ELECTROMAGNETIC FIELDS AND ELASMOBRANCHES

Tidal Energy High Priority Interaction #3

Admiralty Inlet – Puget Sound, Washington

Stressor: Electromagnetic Fields

Receptor: Elasmobranches

Step 1: Description of Technology and Site/Location

This case is based on tidal energy technology deployed in Puget Sound, Washington. A detailed description of the geophysical location and technology used is provided in the Technology and Site Characteristics description at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

High-priority interactions were developed through a process of identifying the high-consequence stressor–receptor interactions. This example reviews the specific information below.

Stressor: EMF **Priority: High**

Issue: Changes to electromagnetic fields may affect elasmobranch behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey.

Step 3: Spatial and Temporal Scale of Stressor

For the tidal power case study, the rotating turbines and power cables connecting the two tidal turbines to the junction box all pose as potential stressors that can produce EMF and affect the various elasmobranchs (receptor) within the project area. The physical dimensions of the stressor are as follows:

- Shroud diameter: 10m(rotor diameter ~ 8 m)
- Distance between each tidal turbine: 30–40m
- Maximum rotational speed: between 15 and 20 rpm
- Transmission cable length: 1km of trunk subsea cable,117mm in diameter
- Cable laid on sea floor, horizontally directionally drilled from approximately 20m depth through intertidal zone.

To further address the spatial scale of EMF as a potential stressor, a map consisting of the power cable routes in Admiralty Inlet could be used to develop the worst-case scenario for areas of EMF exposure to elasmobranchs. Similarly, the EMF profile from power cables as well as the turbine generator could be used to identify additional sources of EMF within the project area.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

A thorough understanding of the baseline environmental conditions in the tidal power project area is likely necessary to analyze how the presence of EMF (stressor) will affect elasmobranchs (receptor). To achieve this, distribution and behavioral data are needed for the shark populations of concern (six-gill shark, basking sharks, and dogfish), including: population distribution, age structure, and reproductive rates; and seasonal and diurnal patterns of movement through the project area (Dundrack and Zielinski 2003; Wood et al. 1979; Andrews et al. 2007; Taylor 2008). As sharks are believed to be attracted to sources of EMF within certain range levels, it is also important to understand shark behavior in the vicinity of the turbines (Normandeau 2011; Kirschvink et al. 2001; Michel et al. 2007). Estimating the potential EMF exposure to sharks also requires a three-dimensional spatial map of the power cable routes from the project site to shore and a temporal profile of when the turbine blades are generating EMF during the tidal cycle.

Step 5: Scientific and Regulatory Thresholds

Protocols used for post-installation monitoring for effects of EMF should ideally be able to detect changes in fish populations that exceed the following scientific and regulatory thresholds, as a result of the installation and operation of the tidal power project.

Scientific Thresholds

The sensitivity of baseline and effects monitoring protocols for elasmobranchs should be able to detect failure to remain below this scientific threshold: Injury to or significant changes in behavior (attraction or avoidance of elasmobranchs. A commercial tidal project in Admiralty Inlet could affect the stability of the population of sharks in Puget Sound, particularly those with small populations such as the six-gill shark and basking shark.

Regulatory Thresholds

The sensitivity of baseline and effects monitoring protocols for elasmobranchs must be able to detect failure to remain below this regulatory threshold: for elasmobranch stocks identified within the *Magnuson–Stevens Fishery Conservation and Management Act* (MSFCMA) and managed by NOAA, the threshold is degradation or removal of essential fish habitat (EFH), defined as the waters and substrate necessary for the spawning, breeding, feeding, or growth to maturity for protected species. Six species of sharks and skates are managed under NOAA Fisheries in the project area: leopard shark, soupfin shark, spiny dogfish, big skate, California skate, and longnose skate (Pacific Fishery Management Council 2011), although only the spiny dogfish is found in large numbers in the project area.

Step 6: Baseline Information Monitoring Needs

Although several studies have analyzed the population dynamics and overall spatial distribution of several of the elasmobranchs expected to use the proposed tidal power project area at a broader scale (Taylor 2008; Wood et al. 1979; Dundrack and Zielinski 2003), there are limited data on the specific populations and distributions of elasmobranchs within Puget Sound and Admiralty Inlet (Andrews et al. 2007). There have been no studies to date of ambient EMF levels in the project area.

Step 7: Effects Monitoring Information Needs

To evaluate the effects of EMF on elasmobranchs in Admiralty Inlet, a characterization of the potential EMF emitted by the power cables and rotating turbine blades should ideally be modeled using realistic EMF levels provided by manufacturers (as much as possible) and the tidal movement over the cables inducing EMF as model inputs. Laboratory tests to determine elasmobranch sensitivity to EMF will provide insight into potential responses and may be used to design monitoring studies. Currently laboratory work is underway in Florida with sharks; protocols may become public in 2012 (Kajiura pers. comm.) and will be carried out in the Pacific Northwest in 2012 with protocols published in late 2012 (Copping pers. comm.). If laboratory studies indicate that the modeled levels of EMF likely in Admiralty Inlet have the potential to cause significant behavioral changes (e.g., avoidance or attraction) in elasmobranchs, monitoring studies will be need to verify the effect, once the turbines are in place.

Step 8: Baseline Monitoring Protocols

Existing Protocols

Stock assessments for sharks and other elasmobranchs have been developed for other locations (Tonachella 2010); several of these methods can be applied to Admiralty Inlet. Several methods have been used to examine the spatial distribution and population dynamics of elasmobranchs throughout Puget Sound and the Pacific Northwest (Dundrack and Zielinski 2003; Wood et al. 1979; Andrews et al. 2007; Taylor 2008).

Protocols That Need Development/Testing

Monitoring protocols specific to the elasmobranch populations and distribution throughout the Whidbey basin and Admiralty Inlet region need to be developed. A protocol for measuring ambient EMF in the region of tidal turbine also needs development; there is some possibility of adapting an EMF protocol that will be designed for wave energy development in 2012 (Wolff pers. comm.). This measurement will be complicated by the large mass of ferrous metal used in many tidal turbine support structures, including OpenHydro turbines proposed for deployment in Admiralty Inlet.

Step 9: Effects Monitoring Protocols

Existing Protocols

Methods have been developed in laboratory studies to analyze the effects of EMF on elasmobranchs (Kimber et al. 2011) and can be applied to the specific elasmobranchs found in the tidal power project area. Other protocols are being developed within this field but have not been released to the public (Kajiura pers. comm.).

Protocols That Need Development/Testing

To assess the potential effects of EMF on elasmobranchs that use the tidal power project area, protocols need to be developed to characterize the potential EMF emitted by the power cables and generator. Laboratory tests will also need to be developed to characterize the sensitivity and behavioral changes of the various shark species to the EMF components at levels resembling those of the power cables and generators. Methods have been developed to test EMF effects on elasmobranchs in a laboratory setting and in the field (Kimber et al. 2011; Gill et al. 2009); however, these are not entirely applicable to the tidal power project area due to the different test organisms and the use of laboratory methods. Protocols to measure EMF levels in the project area emitted from power cables and turbine rotors will also be needed.

6.4 MOVING DEVICES AND RESIDENT MIGRATORY FISH

Tidal Energy High Priority Interaction #3

Admiralty Inlet – Puget Sound, Washington

Stressor: Moving Devices

Receptor: Resident and Migratory Fish

Step 1: Description of Technology and Site/Location

This case is based on tidal energy technology deployed in Puget Sound, Washington. A detailed description of the geophysical location and technology used is provided in the Technology and Site Characteristics description at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Moving Devices **Priority: Medium**

Issue: Rotating turbine blades could present risk to resident fish, migratory fish, and/or sharks from strike (eggs, larvae, juveniles and adults) and entrainment (larvae). The issue is characterized by a high degree of uncertainty.

Step 3: Spatial and Temporal Scale of Stressor

For the tidal power case study, the device frame and rotating turbine blades (stressors) may potentially harm fish (receptors) in the project area if they come into physical contact with the blades. Spatially, the physical dimensions of the stressor are as follows:

- Shroud diameter: 10m(rotor diameter ~ 8 m)
- Overall height: 15 m (seabed to top of shroud)
- Depth: 50–60 m
- Overhead clearance to water surface: ~40m (at lowest astronomical tide)
- Distance between each tidal turbine: 30–40m
- Footprint for individual turbine: $10m^2$
- Footprint depth below seafloor:$<10m^2$
- Maximum rotational speed: between 15 and 20 rpm

Temporally, the scales chosen for the stressor–receptor interaction of turbine blades with fish include the amount of time that the turbine blades are rotating in a tidal cycle and the operational profile of the spinning blades. It is thought that the tidal turbines will be operating on average 68% of the time, or for roughly 16.3 hr in a 24-hr period. Contributing factors include cut-in speed, tidal current speeds through the annual tidal cycle, and asymmetry of tidal currents in the project area.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

To analyze how the OpenHydro tidal turbine blades (stressor) affect the resident and migratory fish (receptors) inhabiting the area, a thorough understanding of the baseline conditions within the project area is needed. To achieve this, distribution and behavioral data are needed for the fish populations of concern, including population distribution, age structure, and reproductive rates; seasonal and diurnal patterns of movement through the study area (portion of water body near turbines); a thorough comprehension of adult and sub-adult fish behavior within the vicinity of the turbines, including the behavior of shoaling resident fish; and an understanding of the temporal profiles of turbine blades spinning during the tidal cycle.

Because Admiralty Inlet serves as the main connection to Puget Sound's Main Basin, it is of high importance for migrating fish into Puget Sound (O'Neill and West 2009). Two threatened salmonid species (Puget Sound Chinook and Hood Canal summer chum) use this area as a migration route to return to their natal spawning grounds. It is also of high importance for residential fish; the federally listed rockfish are known to be widely dispersed throughout the Puget Sound basin, the Yelloweye, boccacio, and canary rockfish have been identified within the Whidbey basin, in proximity to Admiralty Inlet (PSP 2009; Palsson et al. 2009).

Step 5: Scientific and Regulatory Thresholds

Protocols used for post-installation monitoring for fish/turbine interactions should ideally be able to detect changes in fish populations that exceed the following scientific and regulatory thresholds, as a result of the installation and operation of the tidal power project.

Scientific Thresholds

The sensitivity of baseline and effects monitoring protocols for migratory and resident fish should be able to detect failure to remain below two scientific thresholds:

1. Using baseline data, evaluating whether turbine strikes cause or contribute to the death or injury of a sufficient number of individual fish to an extent the stability and reproductive success of the population is threatened. For example, with rockfish this includes large reproductive females, and all reproductive adults for salmonids.
2. A loss of significant numbers of juveniles or larvae for migratory or resident fish that could have an adverse impact on critically small populations.

Regulatory Thresholds

The sensitivity of baseline and effects monitoring protocols for migratory and resident fish must be able to detect failure to remain below two regulatory thresholds:

1. For all fish federally listed as threatened or endangered under the ESA or state listed by the state of Washington as threatened or endangered, the threshold is the detection of a listed species in the project area. Although the ESA prohibits the taking of a listed species through injury or mortality, the act also provides permits for the taking of species incidental to an otherwise lawful activity (ESA Section 10(a)(1)). Known presence and/or detection of a threatened or endangered fish in the project area triggers the need for a developer to obtain an incidental take permit from NOAA

Fisheries under the ESA because moving blades of the OpenHydro tidal turbines could result in a “taking." Within the Admiralty Inlet, federally listed fish are Puget Sound Chinook and Hood Canal Summer chum (threatened), as well as boccacio (endangered), Yelloweye rockfish, and canary rockfish (threatened).

2. For all fish stocks identified within the Magnuson–Stevens Act, the threshold is degradation or removal of essential fish habitat (EFH—the waters and substrate necessary for the spawning, breeding, feeding, or growth to maturity for protected fish species) through the deployment of the OpenHydro tidal turbines. Moving blades on the device may have an indirect effect on EFH because of possible changes in sedimentation to nearby habitat, thus triggering regulatory mandates under the Magnuson–Stevens Act. The nearshore waters in Admiralty Inlet are designated as critical habitat for all salmon species and listed rockfish.

Step 6: Baseline Information Monitoring Needs

Stock assessments for species at risk are carried out by the State of Washington and NOAA Fisheries within Puget Sound (NMFS 2011; Palsson et al. 2009; Pacific Fisheries Management Council 2011); however, there are limited data on salmon and rockfish stocks in the Admiralty Inlet area. A biological assessment of rockfish in Puget Sound was reported in 2009 (Palsson et al. 2009) but lacks detailed information for Admiralty Inlet. There is also a lack of detailed behavior and spatial distribution information for resident and migratory fish in Admiralty Inlet. As such, spatial information throughout the region is available, but a site-specific baseline study is needed to assess the presence and absence of species of concern in the project area.

Step 7: Effects Monitoring Information Needs

To evaluate the effect of the moving tidal turbine blades on resident and migratory fish throughout Admiralty Inlet, an operational profile for the OpenHydro turbines could be developed to model the interaction of fish populations (adults and juveniles/larvae) with the rotating blades (strike and entrainment). Behavioral responses of the migratory and resident fish to the rotating blades should also be gathered for fish species of concern in the vicinity of the turbines, using either direct observations or surrogate measures (observation of other fish species). These observations will be used to validate the behavioral models.

Although no appropriate control site for Admiralty Inlet exists in Puget Sound or a nearby estuary, a reference site such as Race Rocks in the Strait of Juan de Fuca could act as a quasi-control site.

Step 8: Baseline Monitoring Protocols

Existing Protocols

To collect baseline data on how the moving turbine blades may affect the resident and migratory fish within the tidal power project area, several monitoring protocols can be utilized. Capture techniques such as trawling, gill netting, or capture by hook and line have been used extensively to assess fish populations, abundance, age structure, and reproductive rates. These methods may also be used to begin understanding the spatial distributions of fish species

(Palsson et al. 2009; Gunderson and Sample 1980; Beamish et al. 2000). Abundance and overall distribution of rockfish and other fish larvae can be gathered using plankton tows (Moser et al. 2000). Acoustic monitoring, including the use of side-scan, split-beam, and multibeam active acoustics, is appropriate for detecting the vertical and horizontal distribution, (rough) biomass of fish, and hard-bottom habitats, but cannot provide species-level identification without additional information. Optical methods including stereo cameras are somewhat helpful in identifying and quantifying fish species and habitats (Rooper et al. 2010; Kracker 2007). Limited studies of fish populations with ROVs equipped with cameras have been used in Puget Sound (Grove and Shull 2008; Johnson et al. 2003). All of these sampling methods can be repeated on a seasonal/monthly basis to assess temporal profiles.

Protocols That Need Development/Testing

Additional protocol development should ideally focus on methods that can determine the seasonal presence of migratory fish at risk such as Puget Sound Chinook and Hood Canal chum. Protocols need to be established for use of ROVs equipped with high-resolution cameras to assess the abundance, behavior, distribution, and habitat of adult and juvenile rockfish.

Step 9: Effects Monitoring Protocols

Existing Protocols

Changes in populations and individual fish due to the presence of tidal turbines can be assessed using capture, acoustic, and optical monitoring, using the same protocols as those for baseline assessment (Table 6-4). Observations of fish behavior in the vicinity of the turbines may also be pursued using acoustic and optical technologies, although additional testing and assessment of the protocols will be needed. Protocols for measuring fish interaction with tidal turbine blades using acoustic imaging are expected to be published in 2012 (Zydlewski pers. comm.).

Protocols That Need Development/Testing

Monitoring protocols, including high-resolution stereo cameras and acoustic imagery, will need to be developed and tested to assess interactions of resident and migratory fish in proximity to the tidal turbines, including behavioral changes, strike, and entrainment. Equally important to the technical feasibility of collecting this data will be protocols for effectively post-processing high-bandwidth acoustic and optical data to address uncertainties.

Table 6-3 Advantages and disadvantages of monitoring techniques for baseline monitoring of migratory and resident fish.

Technique	Advantages	Disadvantages
Capture Technique: Trawling	• Provide identification of organisms caught • Can be administered at various depths • Suitable method for various scale projects • Feasible at sites accessible by boat	• Difficult to trawl or use net capture techniques in swift tidal waters • Cannot generally be used for juveniles and larvae. • Difficult to gauge broad scale distribution • Difficult to assess seasonal pop of migratory fish
Capture Technique: Plankton Tow	• Provide definite identification of organisms caught • Can be administered at various depths • Capable of capturing larvae/juvenile organisms that would slip through a trawl net	• Difficult to deploy nets in swift tidal waters • Only targeting very small organisms • Difficult to gauge broad scale distribution
High-Resolution Cameras	• Detects broad array of organisms • Observe fish behavior in natural environment • Can assess species identification and strike	• Can be very expensive and technically challenging, particularly in swift tides • Limited to a small area • Can only see organisms of a certain size • May be very difficult to ID fish to species • Need lighting, which will limit assessment at night or modify fish behavior
Acoustic Surveys	• Single beam - locate large schools/groups/biomass of fish; Split beam – locates individuals • Enables a better understanding of overall distribution (vertical and horizontal) in broad area • Can be used pilot/commercial scale • Time efficient • Suitable for migratory and resident fish	• Very difficult to determine quantity or fish species identification
ROVs	• Can be used with other devices such as high resolution cameras • Can be used at several different scales • Can be used to observe fish behavior	• Expensive • Very difficult and hazardous to deploy in swift waters • May be difficult at larger scales

6.5 ENERGY REMOVAL AND SEDIMENT TRANSPORT, WATER QUALITY

Tidal Energy Medium Priority Interaction #5

Admiralty Inlet – Puget Sound, Washington

Stressor: Energy Removal

Receptor: Sediment Transport and Water Quality

Step 1: Description of Technology and Site/Location

This case is based on tidal energy technology deployed in Puget Sound, Washington. A detailed description of the geophysical location and technology used is provided in the Technology and Site Characteristics description at the beginning of this chapter.

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Energy Removal Receptor: Sediment Transport and Water Quality

Priority: Medium

Issue: Changes in circulation due to energy removal could cause changes in water chemistry and farfield changes in sediment patterns in low-energy areas and nearshore. The energy removed from the site includes energy converted to electricity, energy dissipated by drag on support structures, and energy dissipated by the mixing of the wake with the free stream. The latter two energy sinks may be large in comparison to the energy converted to electricity.

Stressor: Energy Removal Receptor: Ecosystem Interactions

Priority: Medium

Issue: Removal of energy and change in flow in tidal basins could cause ”bottom-up” trophic impacts through changes in phytoplankton growth dynamics and the marine or estuarine food web.

These two stressor–receptor interactions are treated together in the case study.

Step 3: Spatial and Temporal Scale of Stressor

For the tidal power case study, the change in water circulation caused by the removal of tidal energy (stressor) may affect water quality and sediment transport processes (receptor). Because changes in water circulation may affect farfield environments, the spatial scale of this stressor includes the main body of Puget Sound. It is unclear how the stressor may affect water quality and sediment transport processes on a temporal scale, but it likely to occur over relative large time scales (years to decades). The extent of the effect of energy removal on water quality and sediment transport may be dependent on the size of the project (number of turbines) and will require additional research and data.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

The tidal turbines in Admiralty Inlet have the potential to affect circulation throughout the portion of Puget Sound south of Admiralty Inlet and, to a lesser degree, in the Straits of Juan de Fuca. Nearfield changes are unlikely due to the strong horizontal and vertical mixing in the area. To analyze how the change in water circulation (stressor) affects water quality and sediment transport (receptor) within Admiralty Inlet and Puget Sound, a thorough understanding of the water circulation and flushing time is needed; predictive power and the ability to determine potential outcomes of deploying the tidal turbines can be derived from numerical models, validated by water quality and sediment transport measurements. The circulation of Puget Sound is fairly well understood, but details of water movement through Admiralty Inlet and the impacts changes in flow might have on farfield processes is unknown.

Step 5: Scientific and Regulatory Thresholds

Protocols used for post-installation monitoring for changes in water quality and sediment transport should ideally be able to detect changes in these parameters that exceed the following scientific and regulatory thresholds, as a result of the installation and operation of the tidal power project.

Scientific Thresholds

The sensitivity of baseline and effects monitoring protocols for water quality and sediment transport should be able to detect whether two scientific thresholds are surpassed:

1. Changes in farfield water quality variables (such as dissolved oxygen levels, nutrient levels, turbidity) that affects living organisms, particularly phytoplankton, bacterioplankton, and heterotrophs that form the base of the marine food web.
2. Changes in sediment transport patterns and deposition that form and maintain benthic and nearshore habitats of importance to species of concern and that support the base of the marine food web.

Regulatory Thresholds

The sensitivity of baseline and effects monitoring protocols for water quality and sediment transport must be able to detect failure to remain below two regulatory thresholds:

1. Energy removal and changes in water flow due to the presence of tidal turbines in Admiralty Inlet will affect farfield circulation patterns. Potential results encompass changes in water quality, including reduced dissolved oxygen in several embayments throughout Puget Sound (i.e., Port Susan, Hood Canal) and other disruptions, such as increased turbidity affecting primary productivity. Under the CWA, no degradation in water quality is permitted. The practical application of the regulatory limits means that, for water quality parameters for which there are CWA limits (such as biochemical oxygen demand, dissolved nutrients, turbidity, and toxic chemicals),changes in farfield water quality or sediment transport must not exceed these limits. Similarly, if energy removal increases flushing time, effluent discharge permits may also require adjustments.

2. Energy removal and changes in flow will similarly change sediment transport rates and deposition patterns. Changes in benthic and/or nearshore habitat resulting from these changes in sediment transport must not affect habitats for species of concern under the *Endangered Species Act*, *Marine Mammal Protection Act*, *Migratory Bird Treaty Act*, or the *Magnuson-Stevens Stevens Fishery Conservation and Management Act*.

Step 6: Baseline Information Monitoring Needs

A high-fidelity three-dimensional hydrodynamic model is needed to determine the circulation and sediment transport for Admiralty Inlet and Puget Sound. The sampling data required to validate this model include total suspended sediment concentration in the water column (profiles and time series), distribution of sediment grain sizes, sediment settling velocity, and sediment cores. Water quality and sediment transport sampling data are needed for the project area in Admiralty Inlet to calibrate the model.

Step 7: Effects Monitoring Information Needs

Studies to Evaluate Effects of Stressor on Receptor

Numerical equivalents of the tidal turbines should ideally be placed in the numerical model created to determine baseline conditions to simulate the removal of energy and changes in flow regime due to the presence and operation of the turbines. Model runs and scenarios are needed to determine the farfield effects on water quality and sediment transport; the major impacts of changes due to tidal turbines are on the tidal residuals, requiring that modeling runs cover long periods of time (years to decades) to ensure effects are measurable and realistic.

Identify Potential Reference Sites with Similar Physical/Biological Characteristics

No reasonable reference sites currently are available in Puget Sound or nearby estuaries to use for similar physical/biological characteristics. Sites like Tacoma Narrows and Race Rocks may provide areas where simulated tidal turbine effects can be modeled to provide some insight into farfield effects, but the basin geometry, water circulation, and habitats differ considerably from those in Admiralty Inlet.

Step 8: Baseline Monitoring Protocols

Existing Protocols

Several numeric modeling efforts are addressing water circulation and particulate transport in Puget Sound, at varying levels of resolution. These include the Finite Volume Coastal Ocean Model (FVCOM) by Pacific Northwest National Laboratory (Yang and Khangaonkar 2010); one-dimensional models (Polagye et al. 2008, 2009); box models (Babson et al. 2006) and the Regional Ocean Modeling System (ROMS) by the University of Washington (under development).

Standardized oceanographic methodologies for measuring water quality variables include the use of conductivity/temperature/depth casts with a bottle rosette to measure dissolved oxygen, dissolved nutrients, chlorophyll, turbidity, and other parameters (Newton et al. 2002).

Methodologies for measuring sediment transport and deposition are also standardized (Strickland and Parsons 1972). In addition, there are various methods available to measure sediment transport (Neill et al. 2009) and evaluate benthic and nearshore habitats (Nichols 1985; WDNR 2009).

Protocols That Need Development/Testing

Methodologies exist for modeling the presence of tidal turbines in Puget Sound, although further refinement is needed. To address temporal variation, data sampling should occur during spring and neap tides as well as at flood, ebb, high, and low tidal phases. Samples could also be collected during the wet and dry seasons to characterize seasonal variation in freshwater input, which affects tidal flushing. Samples could also be collected in the vicinity of and distant from tidal turbines to address the spatial scale of potential water quality and sediment transport changes. Methods for the collection of water quality and sediment transport data are appropriate for farfield post-installation monitoring.

Step 9: Effects Monitoring Protocols

Existing Protocols

The PNNL model (FVCOM) has initial placement of tidal turbines modeled for an idealized version of Admiralty Inlet. There are existing protocols for collecting water quality and sediment transport data.

Protocols That Need Development/Testing

Methodologies for refining the simulation of tidal turbines in Admiralty Inlet are needed to accurately predict farfield water quality and sediment transport changes due to the placement and operation of the tidal turbines.

7 OFFSHORE WIND POWER CASE STUDIES

AUTHORED BY H.T. HARVEY & ASSOCIATES

DISCLAIMER: *The companies referenced in this section were not involved in developing content, analysis, or conclusions. The project information presented in this report is based on the project team's summary of existing public information available at the time of its drafting, and is not endorsed by any company to be representative of any current or planned project.*

Step 1: Description of the Technology and Site/Location

The case study for offshore wind power consists of the installation of 25 6-MW wind turbines on a WindFloat® foundation, manufactured by Principle Power. The WindFloat® foundations are floating foundations fitted with patented water entrapment (heave) plates at the base of each wind turbine column, eliminating the need for heavy construction equipment and drilling to install foundations, and allowing for installation farther offshore in deeper water (Figure 7-1). Each turbine will have some oil or hydraulic fluid within the hub, and four mooring lines per turbine, anchored with pre-laid drag embedded anchors.

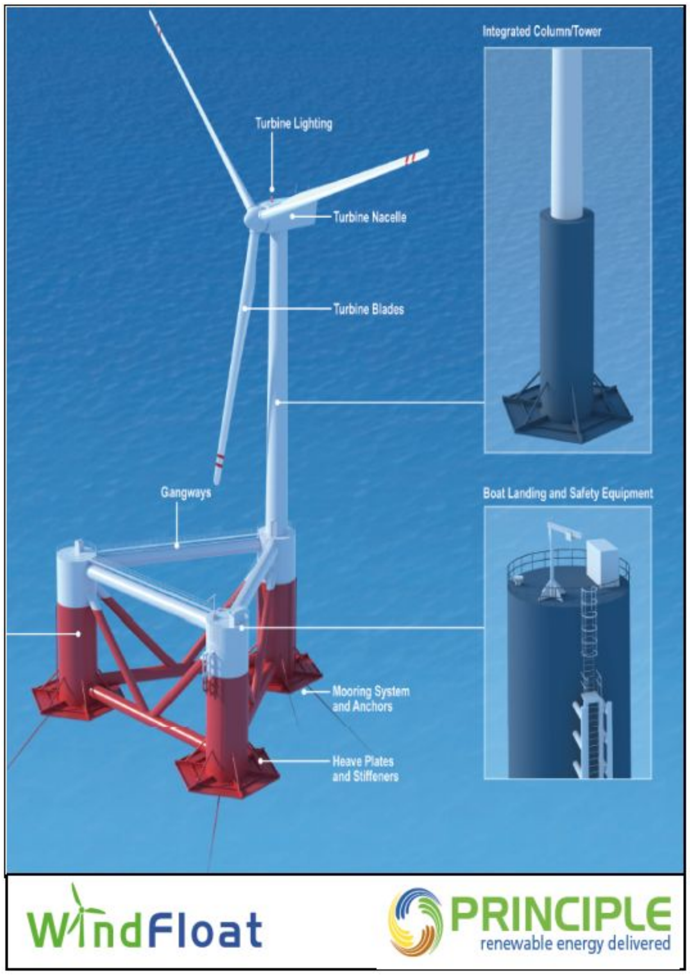

Figure 7-1. Principle Power floating offshore wind turbine

The turbines would be oriented perpendicular to shore 8 km to 16 km (5 mi to 10 mi) offshore of Humboldt Bay (Figure 7.2) at a depth of approximately 70–180 m because the prevailing winds are generally from the northwest or from the north (Figure 7.2). The array will be arranged across a 24-km^2 area that is 8 km long in an east–west orientation and 3 km wide in a north–south orientation. Each turbine would be fully assembled onshore and towed out to its installation site.

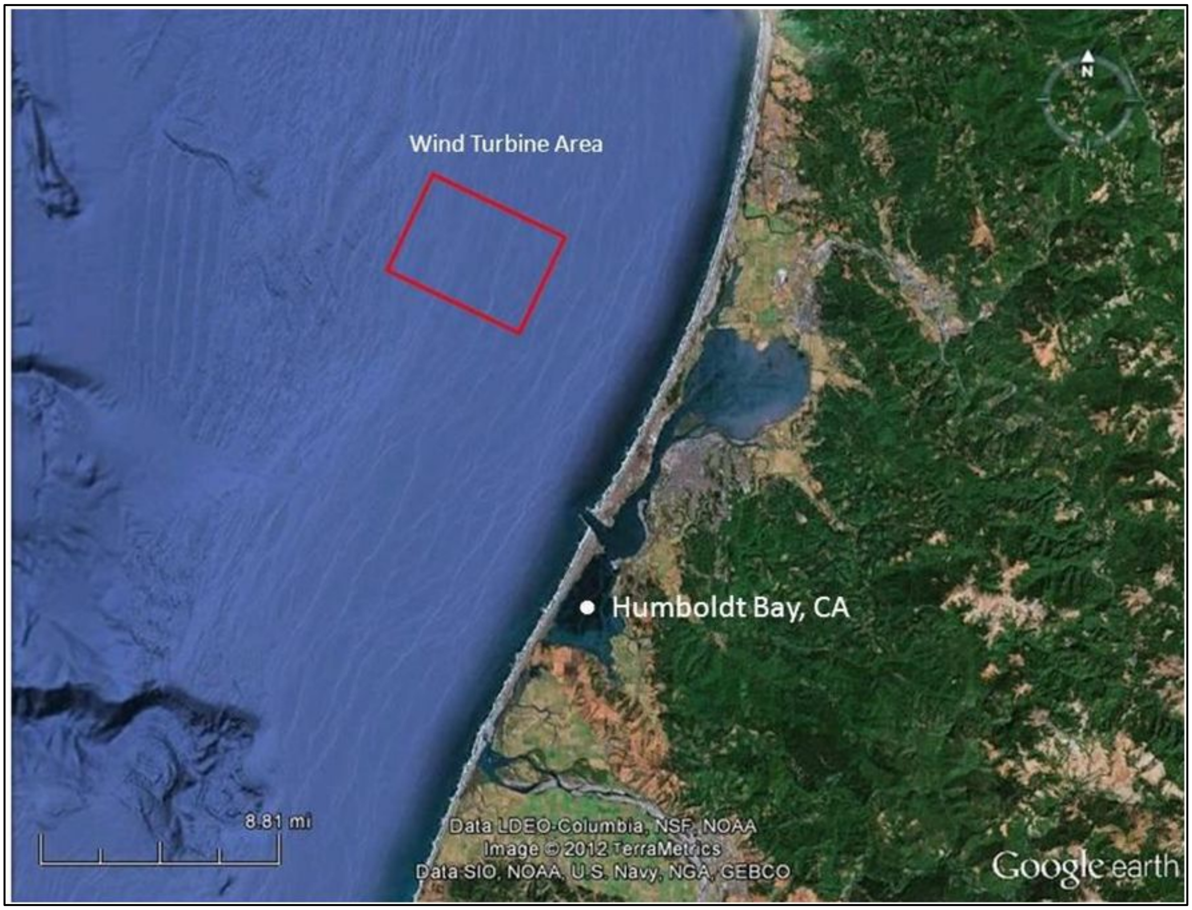

Figure 7-2. Location of the offshore wind case studies.

The project site is near the midpoint of a 40-mile-long littoral cell that stretches from False Cape, located directly north of Cape Mendocino, to Trinidad Head, that contains two major rivers: the Mad River, about 3 km north of the project site, and the Eel River, about 13 km to the south. The seabed at the site is composed of fine-grained sediment (≤16 µm) (Sommerfield and Wheatcroft 2007). Strong north winds blowing in spring and summer result in upwelling of cold, deep water with low oxygen and high nutrients onto the shelf that affects productivity and food webs (Reese and Brodeur 2006).

Humboldt Bay is California’s second largest bay and serves as a deep-water port for northern California and a hub for commercial (e.g., crab, groundfish, albacore) and recreational (e.g., crab, halibut, albacore, salmon and rockfish) fisheries (Pomeroy et al. 2010) and shellfish aquaculture. Numerous marine mammals can be found year-round or migrating through the area, including pinnipeds (e.g., harbor seals) and cetaceans (e.g., gray and humpback whales). Several ESA-listed migratory fishes are likely to utilize the area, including Pacific salmonids and green sturgeon.

Each turbine along the perimeter of the array would be lighted at night with a single flashing red light for aviation safety; the 8 interior turbines would not be lit. Aviation lights would be synchronized, meeting Federal Aviation Administration (FAA) and U.S. Coast Guard (USCG) requirements and using a minimum number of medium- to low-intensity lights, per the U.S. Fish and Wildlife Service (USFWS) guidelines on avoiding and minimizing wildlife impacts from wind turbines (USFWS 2012). Per USCG regulations, marker buoys will provide a physical on-water designation of potential hazards, operational areas, and safe passage locations. All offshore components will have markings and lighting, based on standards from the International Association of Marine Aids to Navigation and Lighthouse Authorities and the USCG. Lights will be shielded to direct light only toward approaching watercraft and not directly upward. Flash intensity will meet the minimum USCG requirement for navigational safety.

Approximately 28 km of submarine inner array cables from each turbine would interconnect within the array and terminate on a support platform located immediately adjacent to the turbine array. Circuit breakers and transformers would be interconnected with the cable systems to transmit power through a shore-connected submarine cable system. The shore-connected submarine cable would be approximately 8 km in length and buried, and would travel east from the support platform to landfall at Samoa, California. In total, approximately 36 km of submarine transmission line would be installed.

Construction equipment, wind turbine components, supplies, and maintenance vessels would be staged at Humboldt Bay. Project proponents would prepare a Spill Prevention Control and Cleanup Plan prior to installation and operation of the facility in order to prevent contamination of wildlife and the environment by accidental discharge.

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to the ocean energy industry and regulatory agencies as it relates to project development, focusing limited resources on those issues most critical to commercial development.

Step 2: Identify Priority Stressor-Receptor Interactions

Environmental interactions can be evaluated from several different perspectives. The project team conducted the following evaluations: 1) expert opinion, 2) regulatory, and 3) stakeholder values. This approach ensured that each interaction was viewed from the different and relevant perspectives that are known to have a major influence on the siting, licensing, and permitting process for commercial-scale ocean renewable energy projects. The expert opinion, regulatory, and stakeholder values evaluations were combined for an integrative analysis. Criteria were developed to determine protocol development priorities. The integrated list is outlined in Table 7-1.

Table 7-1. Offshore wind energy- summary of matrices (see Section 3 for a summary of how these priorities were developed).

A. Static Devices

	Expert Opinion	Regulatory	Stakeholder Values
1. Sediment Characteristics	🟥	🟩	⬜
2. Nearfield Habitat	🟥	🟨	⬜
3. Farfield Habitat	🟨	🟩	⬜
4. Ecosystem Interactions	🟥	🟨	⬜
5. Benthic Invertebrates	🟨	🟩	⬜
6. Nektonic Invertebrates	🟨	🟩	⬜
7. Resident Fishes	🟨	🟨	⬜
8. Migratory Fishes	🟨	🟨	⬜
9. Elasmobranchs	🟨	🟩	⬜
10. Sea Turtles	🟨	🟩	⬜
11. Cetaceans	🟥	🟥	🟨
12. Pinnipeds	🟨	🟨	⬜
13. Bats	🟨	🟨	🟨
14. Birds	🟨	🟥	🟨

B. Moving Devices

	Expert Opinion	Regulatory	Stakeholder Values
1. Bats	🟥	🟥	🟨
2. Birds	🟥	🟥	🟥

C. Energy Removal

D. Chemical Release

	Expert Opinion	Regulatory	Stakeholder Values
1. Sediment Characteristics	🟩	🟩	🟥

E. Noise and Vibration

	Expert Opinion	Regulatory	Stakeholder Values
1. Resident Fishes	🟩	🟨	🟨
2. Migratory Fishes	🟩	🟨	🟨
3. Cetaceans	🟨	🟥	🟥
4. Pinnipeds	🟨	🟩	⬜
5. Bats	🟨		⬜

F. EMF

	Expert Opinion	Regulatory	Stakeholder Values
1. Ecosystem Interactions	🟨	🟨	⬜
2. Benthic Invertebrates	🟨	🟨	⬜

3. Migratory Fishes	🟧	🟥	🟧
4. Elasmobranchs	🟥	🟩	🟧
5. Sea Turtles	🟥	🟧	▨
6. Bats	🟧		▨
G. Boat Traffic			
	Expert Opinion	Regulatory	Stakeholder Values
1. Sea Turtles	🟧	🟧	▨
2. Cetaceans	🟧	🟧	▨
3. Mustelids	🟧	🟧	▨
H. Lights			
	Expert Opinion	Regulatory	Stakeholder Values
1. Bats	🟥	🟧	▨
2. Birds	🟥	🟥	🟥

The complete list of high and medium priority interactions for offshore wind energy is identified in Chapter 3. Listed below are the interactions selected for case studies:

- *Static/Moving devices and birds.* Birds could collide with wind turbines while flying through the area. Birds could also change their behaviors in response to wind turbines, through either avoidance of the turbines (increasing energetic requirements) or attraction to the turbines (increasing risk of collision).
- *Static devices and ecosystem interactions.* A change to nearfield habitat is expected to change species composition and their interactions with one another. Underwater hard structures may serve as fish attractors (FAD effect or reef effect), attracting a different assemblage than would have been found over sand, and could provide habitat for jellyfish polyps. Changes to grain size will affect infaunal organism assemblages.
- *Moving devices and bats.* Bats could collide with wind turbines while flying through the area or be injured or killed from barotrauma (i.e., pressure drop). Bats could also change their behaviors in response to wind turbines, through either avoidance of the turbines (increasing energetic requirements) or attraction to the turbines (increasing risk of collision).
- *Static devices and collision with sea turtles, bats, birds.* Sea turtles could collide with structures and become entangled in mooring lines. Lost fishing gear in the marine environment could become entangled in the mooring lines, increasing the likelihood that sea turtles will become entangled. Behavioral changes associated with avoiding installations may result in different energetic requirements or feeding opportunities. Bats and birds could collide with offshore wind turbine support towers above the surface of the water.

7.1 MOVING DEVICES/STATIC DEVICES AND BIRDS

Offshore Wind High Priority Interaction #1

Humboldt County, California

Stressor: Moving Devices and Static Devices

Receptor: Birds

Step 1: Description of Technology and Site/Location

This case study is based on offshore wind energy technology (Figure 7-1) that would be deployed in Humboldt County, California (Figure 7-2).

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Moving Devices Priority: High

Issue: Birds could be struck by the wind turbines while flying through the area. Birds could also change their behaviors in response to wind turbines, either through avoidance of, or attraction to, turbines. Collision risk likely increases during high winds (birds tend to fly higher) and poor visibility.

Stressor: Static Devices Priority: Medium

Issue: Birds could collide with wind turbine support towers above the surface of the water. Birds could also be attracted to support towers and structures for roosting. Collision risk increases during conditions when visibility is poor (e.g., foggy conditions).

Step 3: Spatial and Temporal Scale of Stressor

For the Humboldt Offshore Wind Power case study, the stressors are the wind turbines (moving devices) and the support poles and platforms for the turbines (static devices) that could affect birds (receptor) in the project area. The project footprint surrounded by a buffer of 3 km is considered the impact area (Vaneman and Stienen 2009). The three-dimensional footprint of the stressors is as follows:

- Rotor diameter:120–150 m
- Turbine hub height: 80–90 m
- Overall height: 140–165 m
- Generating capacity: ±6 MW with a cut-in wind speed of approximately[3] 4 m/s
- Distance between each wind turbine: 1 km
- Array footprint for 25 turbines: 24 km^2

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[3] http://www.wind-energy-the-facts.org/en/part-i-technology/chapter-2-wind-resource-estimation/local-wind-resource-assessment-and-energy-analysis/the-annual-variability-of-wind-speed.html

- Array will be 8 km long in an east–west orientation × 3 km wide
- Hull draft approximately 20 m, hull structure above water approximately 10 m or less.

The temporal scale of the stressors is the duration of the project. However, during any time that the turbines are not rotating, they effectively become static devices.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

To conduct an effects analysis, it is necessary to determine the overlap between birds (receptor) and moving and static devices (stressor). To assess baseline conditions in the project area and assist with determining potential effects of the stressors on birds, the first step is to assemble all available information on the following distribution and behavior characteristics: proximity of breeding locations or colonies to the stressor; the annual, seasonal, and diel distribution of these species; if there are any feeding locations that are used consistently by birds; if any of the species exhibits avoidance or attraction behaviors to structures or turbines; flight pathways and timing; and flight characteristics such as flight height, speed, and flocking behaviors during flight.

Bird distribution information specific to the Humboldt Offshore Wind Power Project project area is variable and limited (e.g., Harris 2006). However, the nearshore waters from Trinidad to Crescent City, California, have been identified as a “hotspot” for multispecies aggregation of seabirds (Briggs et al. 1987; Nur et al. 2011). There is boat survey information focused on marbled murrelets, although other seabirds were noted, in the nearshore waters (from shore to 5 km) of Humboldt County conducted by Redwood Sciences Lab in 1989–2009 (Miller et al. 2010). Known breeding locations or colonies in the area include an alcid nesting colony on offshore rocks in Castle Rock National Wildlife Refuge near Crescent City; alcid nesting colonies offshore of Trinidad; and nesting by the federally threatened marbled murrelet in old growth redwood forests of Redwood National and State Parks. Of the species groups known to occur in the project area, alcids, storm-petrels, shearwaters, and albatrosses are known to be attracted to lights; however, these species are unlikely to be attracted to the navigational lights that would be on the wind turbines. Gulls, cormorants, and pelicans could be attracted to the wind turbine platforms for roosting. Many of the seabird species that could occur offshore of northern California are known to exhibit flocking behaviors, especially when foraging (Briggs et al. 1987). Information on flight speed and likely flight direction as affected by wind speed and direction for some California seabirds also is available (Spear and Ainley 1997a, b).

Some information on flight height of West Coast seabird species is available from an avian radar study for a proposed nearshore wave energy development project sited northwest of Reedsport, Oregon (Geo-Marine, Inc. 2011). Although the Oregon wave energy study surveyed in nearshore waters only (up to 5 km from shore), most of these seabird species would also be expected to occur in the Humboldt Offshore Wind Power Project project area. The Oregon wave energy study found that the majority of seabirds (75–83%) were flying from 1–9 m above sea level, far below the strike zone for the turbines that would be used in the Humboldt Offshore Wind Power Project.

The threatened or endangered seabird species that could occur in the Humboldt Offshore Wind Power Project project area include the federally listed marbled murrelet and short-tailed albatross, and the State-listed Xantus's murrelet. However, marbled murrelets are not likely to be in the project area on a regular basis, as they are generally distributed within 2 km from shore (Strachan et al. 1995; Hébert and Golightly 2008). Short-tailed albatross are exceedingly rare, with few records reported for the region (Harris 2006), and they primarily occur along the continental shelf margin (USFWS 2008; Suryan et al. 2006), seaward of the project area. Numbers of this species are increasing with successful management efforts and occurrences on the west coast of North America are likewise increasing (USFWS 2008) and, as this species increases, inshore records are likely to increase as well, reflecting former patterns of occurrence when the species was more abundant. Xantus's murrelets nest in offshore islands in southern California and Baja California, Mexico and are generally only expected to occur in the project area in fall (Harris 2006), and primarily, but not entirely seaward of the continental shelf break (Briggs et al. 1987); however, since the turbines are not located within California state waters, the state has no jurisdiction.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for birds should be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Humboldt Offshore Wind Power Project.

Scientific Thresholds

Baseline and effects monitoring should detect if one of the following two scientific thresholds is exceeded for bird species that could occur in the Humboldt Offshore Wind Power Project area:

1. Strikes with turbines or support towers causing or contributing to population declines; or
2. Significant proportion of population being directly killed or injured by strikes with turbines or support towers, or indirectly by altering behavior (avoidance of turbines or attraction to towers or lighting).

Regulatory Thresholds

Baseline and effects monitoring should also determine if one of the following two regulatory thresholds is exceeded for birds that could occur in Humboldt Offshore Wind Power Project area:

1. For all bird species listed as federally threatened or endangered or listed by the State of California as threatened or endangered, the threshold is to kill, harass, or injure one individual. In the project area, federally listed bird species include the marbled murrelet and short-tailed albatross; state-listed bird species (Xantus's murrelet) would not be considered because the project is located outside of state waters, although the species is a candidate for federal listing.
2. All birds that could occur in the project area are protected by the Migratory Bird Treaty Act (MBTA), and the threshold is mortality of a single bird. There are over 50 species of birds that could occur in the project area; species groups that may occur

include albatrosses, shearwaters, storm-petrels, pelicans, cormorants, waterfowl, phalaropes, gulls, jaegers, alcids, and shorebirds (Zamon 2008).

Step 6: Baseline Information Monitoring Needs

There is variable, but generally limited, information about the seasonal, interannual variability, and feeding locations of seabirds in the project area. This information would help determine which species of seabirds, and to what extent, they use the project area.

Step 7: Effects Monitoring Information Needs

Outside of general information on flight speed and direction related to wind conditions (Spear and Ainley 1997a, b), there is little or no existing specific information about seasonal or daily flight pathways and limited information about the flight altitude of seabirds in the Humboldt Offshore Wind Power Project area. To evaluate the effect of moving and static devices on seabirds in the project area, information about seasonal or daily flight pathways, flight altitude, and flocking behaviors should ideally be collected and used to model potential encounter and collision rates of different seabird species with the wind turbines.

Step 8: Baseline Monitoring Protocols

Existing Protocols

To collect baseline information about seabirds that may occur in the vicinity of an offshore wind installation, one of the following monitoring protocols can be used to determine seasonal, interannual variability, and foraging locations of seabirds. In general, only one of the transect survey techniques (boat surveys or aerial surveys) would be selected. Transect surveys are used to estimate density or relative abundance of seabirds in the area surveyed (Anderson et al. 1979). In addition, satellite or radio-tracking could be used to obtain detailed information about foraging locations, daily movements, and home ranges of individual birds.

- **Boat Surveys**. Seabirds can be surveyed at sea from ships using strip-transect survey methods described in Tasker et al. (1984) and Briggs et al. (1987) and later modified by Clarke et al. (2003) and Spear et al. (2004). Transect spacing can be adjusted dependent on the scale necessary to detect effects of structures, and all birds would be surveyed from a survey platform at 1-min or 5-min intervals (depending on desired resolution and size of the study area) while the ship is traveling at a cruising speed of 10 knots (Camphuysen et al. 2004). This method would be used to estimate the density and abundance of birds in the area surveyed (Clarke et al. 2003; Camphuysen et al. 2004). Bird behavior, flight height, and direction of flying birds, and oceanographic variables such as sea surface temperature and salinity can also be recorded.
- **Aerial Surveys.** Seabirds can be surveyed from a small, fixed-wing aircraft flying at about 65–80 m altitude at cruising speeds of 165–185 km/hr using aerial transects (Briggs et al. 1987; Camphuysen et al. 2004; Certain and Bretagnolle 2008). Transect spacing can be adjusted dependent on the scale to detect effects of structures. This method would be used to estimate the density and abundance of birds in the area surveyed (Camphuysen et al. 2004).

- **Satellite or Radio tracking.** The movements of individual birds can be tracked with radio transmitters (Perrow et al. 2006) or satellite transmitters (Burger and Shaffer 2008; Mellor and Maher 2008). Birds are captured either on the water or at their colony, fitted with radio or satellite transmitters, and then released. Tracking of birds with radio transmitters occurs via boat, shore, or from an aircraft, and location data of birds with satellite transmitters is transmitted via satellite, enabling data recovery remotely. In general, this method is used for only a few individuals of a single species, and the data can be used to identify key foraging or activity areas, daily movements, and home range size. Satellite tracking data can be merged with remotely sensed environmental data (i.e., chlorophyll concentration, sea surface temperature) to characterize pelagic habitat used by seabirds.

Study Design for Baseline Monitoring of Seabirds

- **Boat Surveys or Aerial Surveys.** The selected monitoring technique would be conducted with the goal of detecting a population-level change for any bird species observed in the project area. To determine the level of effort needed to detect a change (e.g., number of transects per year, number of transects per survey, orientation of individual transects), power analyses should be performed on the data collected during the first few surveys. Power analysis should also address the range of effect size because small effects may be important to regulatory agencies; however, the level of effort necessary to detect small effects may not be feasible. Oceanographic variables such as sea surface temperature, salinity, distance to shore, and bathymetry can also be recorded during surveys by boat; these can serve as explanatory variables of bird abundance and increase the statistical power of detecting changes in bird numbers (MacLean et al. 2006). Surveys would likely be for a minimum of 1 year prior to installation of offshore wind turbines if existing baseline data are not sufficient to meet the requirements of the permitting agencies. However, it is not necessary to conduct pre-project surveys to detect a population-level change, if an adequate number of control sites are also surveyed along with the project area (Underwood 1994; Martins et al. 2009). The project footprint surrounded by a buffer of 3 km would be surveyed as the impact area (Vanerman and Stienen 2009), and two or more areas of identical size and with similar oceanographic characteristics (i.e., similar depth, distance from shore, distance from fronts, bottom substrate, water temperature) outside the project area would be surveyed as the control sites (Underwood 1994; Martins et al. 2009). During each year of the study, surveys should be conducted throughout the year to incorporate seasonal variation of seabirds (see Briggs et al. 1987). The number of replicate surveys would be determined from the power analysis. For each survey, the entire study area should be surveyed in 1 day, if possible.
- **Satellite or Radio tracking.** The selected monitoring protocol (satellite or radio-tracking) would be conducted with the goal of tracking individual movements of seabirds or shorebirds to determine if their use of the project area for foraging or migration. Both methods have been widely used; satellite tracking is often used for larger and wider-ranging seabirds such as albatross, while radio tracking is used for smaller birds with smaller home ranges such as terns, shorebirds, and alcids that are

unable to carry the larger satellite tags. This method is best for obtaining detailed information about a species of concern that is known or suspected to use the project area on a regular basis, such as a listed species with a nearby nesting colony. Tracking would be conducted during the year prior to installation of offshore wind turbines if existing baseline data are not sufficient to meet the requirements of the permitting agencies. To obtain sufficient data to assess key foraging locations, daily movements, colony use and visitation, and to account for potential transmitter loss or failure, a number of individual seabirds of a single species (i.e., > 10 birds) would be captured and fitted with transmitters. Satellite transmitters can last up to 4 months or more (Suryan et al. 2006), while radio transmitters generally have a shorter life span of 4 months or less; thus, a radio-tracking study would not obtain year-round data.

Protocols That Need Development/Testing

- **High-Definition Aerial Survey** is not yet a widely used technique for estimating density or relative abundance of seabirds in the United States, although it has been applied in Europe (e.g., Mellor and Maher 2008; Thaxter and Burton 2009). This technique involves conducting aerial surveys using a small, fixed-wing aircraft that flies at a minimum height of 450 m. Seabirds, marine mammals, and possibly sea turtles are surveyed using high-definition video imagery or still photographs to record seabirds below the aircraft. Images are processed and analyzed after flights are completed. Three different protocols for this technique are described in Thaxter and Burton (2009); a protocol for high definition video surveys is also described in Mellor and Maher (2008). In addition, a high-definition aerial survey monitoring protocol for offshore wind installations is currently being developed by Normandeau Associates through funding awarded by BOEM; a revised protocol may result in more use of high-definition aerial surveys in the future for offshore wind installations in the United States

Doppler weather surveillance radars, also known as WSR-88 or NEXRAD are long-range radars found throughout the United States that can be used to study bird movement patterns including density, speed, and direction, and can be particularly useful for documenting nocturnal migration. This technique has a number of limitations, and would be best used for examining coarse-scale migration patterns of large numbers of birds at high altitudes (e.g., >250 m) and should be used in conjunction with other techniques (i.e., marine radar) to examine finer-scale, site-specific and target-specific movement patterns at lower altitudes. U.S. Geological Survey and other researchers have been assessing the potential applications of this technology (Ruth et al. 2008).

Selecting a Protocol for Baseline Monitoring of Seabirds for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may have the statistical power to detect change at only the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean or open ocean), is also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-2 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed.

Table 7-2. Advantages and Disadvantages of Monitoring Techniques for Baseline Monitoring of Seabirds.

Technique	Advantages	Disadvantages
Boat Surveys	• Bird behavior, flight height, and flight direction can be observed and recorded • Can be conducted before and after wind turbine installations • Suitable method for pilot or commercial scale projects, if project area is large enough to contain multiple transect lines • Feasible at any site that is accessible by boat • Can be used to determine if birds are using the project area	• May cause some disturbance to birds and alter behavior • Poor method to survey marine mammals and sea turtles due to lower range of visibility; aerial surveys provide better vantage point and increased visibility • May not be able to complete survey in 1 day if survey area is large (i.e., >50 km^2) • Cannot survey at night, in poor sea conditions, or in fog • Potential for observer bias
Aerial Surveys	• Marine mammals and possibly sea turtles can also be surveyed • Can be conducted before and after wind turbine installations, if safe to fly between turbines • Large areas can be surveyed faster than with boat surveys • Suitable method for pilot or commercial scale projects, if project area is large enough to contain multiple transect lines • Feasible at any site that is accessible by aircraft • Can be used to determine if birds are using the project area	• May cause some disturbance to birds and alter behavior • Bird behavior and flight height cannot be determined; flight direction difficult to determine • Species identification less reliable than boat surveys • Cannot survey at night, in high winds, or in fog • Potential for observer bias

Radio tracking	• Provides detailed location and movement information of individual birds, can be used to determine if they are using the project area • Suitable method for pilot or commercial scale projects, regardless of project area size • Feasible at any site that is accessible by aircraft, boat, or from shore • Can be used on small birds (i.e., alcids, terns, and shorebirds) • Best for species suspected or known to occur regularly in the project area	• Does not provide information about bird abundance, distribution, or species composition • Does not provide detailed enough information about flight characteristics to model collision risk • Short transmitter battery life (<4 months) limits length of study • Capture of birds and transmitter attachment is invasive and can affect bird behavior and health • Can take considerable effort and cost to track birds; best for birds with small home ranges

Satellite Tracking	• Provides detailed location and movement information of individual birds, can be used to determine if they are using the project area • Satellite transmitters can be programmed to report locations 24 hr/day with a shorter battery life/tracking duration, or duty-cycled (e.g., report every 1–3 days) to conserve battery life and increase tracking duration • Suitable method for pilot or commercial scale projects, regardless of project area size • Feasible at any site because birds are tracked remotely • Best for species suspected or known to occur regularly in the project area	• Does not provide information about bird abundance, distribution, or species composition • Does not provide detailed enough information about flight characteristics to model collision risk • Capture of birds and transmitter attachment is invasive and can affect bird behavior and health • Transmitter detection is dependent upon satellite location and availability and detection frequency could be limited in some areas • Satellite transmitters too heavy for smaller seabirds (i.e., terns), although technology is improving and transmitter weights are declining

The selected protocol for evaluating bird distribution for the Humboldt Offshore Wind Power Project would likely be aerial surveys because this technique is cost-effective, can be used after installation of the wind turbines, and should yield sufficient information about the distribution of seabird species, marine mammals, and potentially sea turtles in the project area. Boat surveys would be conducted concurrently to validate the species identified during aerial surveys and to determine flight height of bird species that occur in the project area.

Aerial surveys and boat surveys would be conducted in the project area and in two to three control areas for 1 year prior to installation of the wind turbines if baseline information is required by the agencies, and then for at least 1 year after installation of wind turbines. Surveys of the project area and at each of the control areas would be conducted several times throughout each year (number determined by the results from the power analysis from the first few surveys), and each replicate survey would be conducted in a single day. A comparison of seabird distribution at the wind turbines at the project area and control areas before and after installation would determine if the scientific and regulatory thresholds may have been exceeded by determining if the turbines are causing or contributing to population declines or if seabirds are avoiding the turbine area.

Satellite or radio tracking would not likely to be used for the Humboldt Offshore Wind Power Project because the listed species that could occur in the project area (marbled murrelet, short-tailed albatross, and Xantus's murrelets) are not expected to occur on a regular or semi-regular basis in the project area, nor are there other species of particular concern (i.e., due to proximity to a nesting colony) that are expected to regularly occur in the project area. However, if baseline aerial surveys identify a seabird species that is particularly abundant in the project area, a satellite or radio-tracking study could be developed for that species to obtain more detailed information about its use of the project area.

Step 9: Effects Monitoring Protocols

Existing Protocols

To assess the potential effect of offshore wind energy projects on birds, flight characteristics (i.e., altitude, speed, direction) and migration routes of birds can be monitored by using either radar alone or radar in conjunction with thermal imagery. Radar detects the trajectories of flying birds but species identification can be difficult, while thermal imagery can be used to help determine size/species of bird, distinguish individual birds within a flock, and also detect collisions with turbines (Desholm et al. 2004; Gauthreaux and Livingston 2006; Hüppop et al. 2006). Data from radar and thermal imagery monitoring are used to model collision risk (Desholm et al. 2004; Desholm et al. 2006). Radar and thermal imagery equipment require a stable platform for mounting, such as on a ship anchored in calm seas, on a jack-up lift boat, on land, or on an offshore platform (i.e., potentially on a platform associated with the wind turbine installation).

In addition to radar or radar/thermal imagery monitoring, monitoring protocols used in baseline studies may also be repeated to compare pre- and post-installation results. This could include one of the transect survey techniques (aerial surveys or boat surveys) and satellite or radio tracking.

- **Radar.** Two radars would be mounted as follows: horizontally mounted radar, which maps the trajectories of flying birds or flocks of birds in time and space; and vertically mounted scanning radar, which measures the altitude at which birds are flying. Horizontal radar can detect birds up to 11 km from the radar, and vertical radar can detect birds up to 2 km in altitude, although the range is dependent upon the specific type of radar selected (Desholm et al. 2004; Geo-Marine, Inc. 2004; Gauthreaux and Livingston 2006; Hüppop et al. 2006). The radar data would be either logged and processed using an automated system, or flight paths would be manually traced using a transparency mounted over the screen and then digitized and entered into a geographic information system (GIS) database. Manual tracing, although more time-consuming, allows for interpretations by the observer. Visual observations from a boat should also be conducted on several occasions to validate the radar data (Walls et al. 2009). Protocols for this technique are described in Desholm et al. (2004) and Geo-Marine, Inc. (2004).

- **Radar and thermal imagery**. A vertically mounted thermal imagery camera can be used in conjunction with vertically mounted radar to help identify species, flock size, and flight altitude (Hüppop et al. 2006; Gauthreaux and Livingston 2006). Thermal images are video-recorded for later processing, and specialized hardware capable of storing the large amounts of continuous video data is needed. Thermal imagery is capable of detecting collisions with turbines, although collisions are generally exceedingly rare and difficult to detect; therefore, a large number of thermal cameras would be needed to detect collisions (Desholm et al. 2006).
- **Boat Surveys, Aerial Surveys, Satellite or Radio tracking.** See Table 7-2 for a description of these techniques.

Study Design for Monitoring Effects on Seabirds

- **Radar or Radar/Thermal Imagery.** Radar or radar/thermal imagery surveys would be conducted for a minimum of 1 year prior to installation of wind turbines, if existing baseline data are not sufficient to meet the requirements of the permitting agencies, and if a stable platform for mounting equipment can be achieved. Radar or radar/thermal imagery surveys should also be conducted for a full year after installation of wind turbines to capture seasonal variability of flight characteristics and migratory patterns (Hüppop et al. 2006). The data collected from radar and thermal imagery, such as flock size, flight height, speed, and direction, could be used to model collision risk of individual bird species (Desholm et al. 2004). After installation of wind turbines, avoidance behaviors of birds can also be detected. The goal of the analysis is to determine which bird species are at risk for collisions with turbines throughout the year, and to model the energetic responses of avoidance responses to predict impacts at the population level (Fox et al. 2006). The risk of collision is assessed at four levels of potential conflict: the study area, the wind turbine installation, the horizontal reach of wind turbine rotor-blades, and the vertical reach of rotor-blade (Desholm et al. 2006). The collision prediction model uses this information to predict number of birds that would collide with the turbines and the number of birds that would avoid (either by chance or by evasive actions) colliding with the turbines. Because these techniques often cannot distinguish species, boat surveys or aerial surveys are usually also needed.
- **Boat Surveys, Aerial Surveys, Satellite or Radio tracking.** See Table 7-2 for a description of these techniques.

Protocols That Need Development/Testing

Acoustic monitoring of birds using microphones can be used to detect vocalizing songbirds and estimate flight height at an offshore wind installation. This method has been used to monitor vocalizing songbirds at wind installations on land (e.g., CWS 2006). However, their application at offshore wind installations is problematic due to significant wind, wave, and precipitation noise, which reduces detection capability (Walls et al. 2009). In addition, its use is limited to vocalizing birds, and many seabird species do not vocalize in flight. An acoustic/thermographic monitoring protocol for offshore wind installations is currently being developed by Normandeau Associates through funding awarded by BOEM; this protocol will deploy acoustic and thermographic detection devices that operate remotely and continuously (24 hr/day) and estimate flight altitude of recorded birds. The use of mechanical vibration sensors to detect collision events is being developed but requires that vibrations from colliding birds can be detected from background turbine vibration (Desholm et al. 2006).

The Northwest National Marine Renewable Energy Centers at Oregon State University and University of Washington, with funding from the Department of Energy, are designing, testing, and deploying an integrated sensor array to continuously monitor interactions (including impacts) of birds and bats on blades, nacelles and towers of wind turbines using a synchronized array of sensors including accelerometers, visual and infrared spectrum cameras, and acoustic monitors. The monitoring system will be designed to run continuously and at several turbines in parallel, with remote access to recorded images and sensor data to quantify interactions, including collisions, and identify organisms involved to the lowest taxonomic grouping possible.

Selecting a Protocol for Effects Monitoring of Seabirds for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may only have the statistical power to detect change at the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean or open ocean), are also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-3 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed. Because the different techniques provide different but limited types of information, several different techniques may be selected to provide a thorough evaluation of potential effects on seabirds.

The selected protocol for determining the flight characteristics of seabirds for the Humboldt Offshore Wind Power Project would be vertical radar and thermal imagery after installation of the wind turbines. It would not be feasible to conduct radar and thermal imagery monitoring prior to installation of the wind turbines because of the lack of a stable platform and the high seas that often occur in the project area. One radar and thermal imagery camera would likely be installed at the project site, assuming the turbine platforms were sufficiently stable, and the vertical radar would likely cover the entire wind turbine array. The data collected from radar and thermal imagery would be used to model collision risk of individual bird species (Desholm et al. 2006). Aerial surveys and boat surveys would be continued as well, to compare pre- and post-installation seabird species composition and abundance in the project area and to gather flight height data to inform the radar/thermal imagery surveys. This information can be used to determine if the scientific and regulatory thresholds are being exceeded by determining if the turbines may cause or contribute to population declines, or if threatened or endangered species could be killed or injured by the turbines.

Table 7-3 Advantages and Disadvantages of Techniques for Monitoring Effects of Offshore Wind Power on Birds.

Technique	Advantages	Disadvantages
Radar	• System can be automated and data recorded continuously, day and night • Bats can also be surveyed • Detects the trajectories of flying targets • Suitable method for pilot or commercial scale projects	• Requires stable platform for mounting equipment and power supply (Duberstein et al. 2011) • Cannot detect collisions • Ability to detect birds (particularly low-flying birds) impaired by rain, fog, and waves; which is also when seabirds may be most vulnerable to collisions with turbines (Duberstein et al. 2011) • Difficult to identify birds to species, although validation using boat-based surveys can increase certainty (Duberstein et al. 2011) • Horizontally scanning radar often has sea clutter, obscuring flying targets or producing false bird tracks (Duberstein et al. 2011)
Radar and Thermal Imagery	• System can be automated and data recorded continuously, day and night • Bats can also be surveyed • Detects the trajectories of flying targets • Some limited ability to determine bird species/size • Can distinguish individual birds within a flock and detect collisions with turbines • Suitable method for pilot or commercial scale projects	• Requires stable platform for mounting equipment and power supply • Ability to detect birds (particularly low-flying birds) impaired by rain, fog, and waves; which is also when seabirds may be most vulnerable to collisions with turbines • Thermal imagery camera needs hardware capable of storing and processing large amounts of data • Operational viewing distance of thermal cameras only 1–2 km (Walls et al. 2009) • Technology is evolving rapidly, would need to field test equipment and software prior to use • Thermal imagery cameras expensive (>$30,000/camera in 2006), but costs are decreasing (Gauthreaux and Livingston 2006, Kunz et al. 2007)
Boat Surveys, Aerial Surveys, Satellite or Radio-Tracking: see Table 7-2 for advantages and disadvantages of these techniques		

7.2 STATIC DEVICES AND ECOSYSTEM INTERACTIONS, NEKTONIC INVERTEBRATES, RESIDENT FISHES, MIGRATORY FISHES, ELASMOBRANCHS

Offshore Wind High Priority Interaction #2

Humboldt County, California

Stressor: Static Devices

Receptor: Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, Elasmobranchs (hereafter, Fish and Invertebrates)

Step 1: Description of Technology and Site/Location

This case study is based on offshore wind energy technology (Figure 7-1) that would be deployed in Humboldt County, California (Figure 7-2).

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Static Devices Receptor: Ecosystem InteractionsPriority: High

Issue: Underwater hard structures may serve as fish attractors (FAD effect or reef effect), attracting a different assemblage than would have been found over soft bottom habitat.

Stressor: Static Devices Receptor: Fish and Invertebrates Priority: Medium

Issue: The addition of hard substrate may result in attraction of these receptors to the project area (FAD effect or reef effect).

Step 3: Spatial and Temporal Scale of Stressor

For the Humboldt Offshore Wind Power case study, the underwater structures including support poles, anchors, mooring lines and foundations for the turbines are the static devices (stressors) that could affect fish and invertebrates (receptor) in the project area. These structures would be present for the life of the project (assumed 30+ years). All of the following features would constitute the project area for ecosystem interactions:

- Array footprint for 25 turbines: 24-km^2 area that is 8 km long in an east–west orientation and 3 km wide in a north–south orientation
- Depth: 70–180 m
- Distance between each wind turbine: 1 km
- Foundation hull draft: approximately 20 m
- Mooring system includes four mooring lines per turbine, anchored with pre-laid drag embedded anchors.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

To conduct an effects analysis, it is necessary to determine the overlap between marine fish and invertebrates (receptors) and static devices (stressor). To assess baseline conditions in the project area and assist with determining potential effects of the stressors on marine fish and invertebrates, the first step is to assemble all available information on the following distribution and behavior characteristics: proximity of spawning locations or nursery habitats to the stressor; the annual, seasonal, and diel distribution of these species; if there are any feeding locations that are used consistently (e.g., hotspots, *sensu* Reese and Brodeur 2006); if any of the species exhibits avoidance or attraction behaviors to structures or turbines; and migratory habitats and timing.

Fish and invertebrate distribution information specific to the vicinity of the Humboldt Offshore Wind Power Project project area is mixed: no specific studies have been conducted in the project project area. However, information exists based on commercial fisheries (Pomeroy et al. 2010) and studies in the area and in similar habitats off Oregon. Commercial fisheries in the area target groundfish (various flatfishes, roundfishes, and rockfishes; *Sebastes* spp.), Dungeness crab (*Cancer magister*), Chinook salmon, albacore tuna (*Thunnus alalunga*), Pacific whiting (*Merluccius productus*) and Pacific Ocean shrimp (*Pandalus jordani*) or pink shrimp (Pomeroy et al. 2010). Species most likely to occur in the project project area are groundfish (especially flatfish, Pacific whiting), pink shrimp, and, during El Niño conditions, albacore. Dungeness crab can occur at depths as great as 750 ft, but the fishery occurs primarily within state waters (3 nautical miles from shore) in depths less than 300 ft (Hankin and Warner 2001). Of the fish species known to occur in the project area, rockfish, lingcod, and potentially green sturgeon could be attracted to the structures. Invertebrate species that could occur in the project area include scyphozoan jellies, which are important prey for leatherback sea turtles (Graham 2009).

The threatened or endangered fish species that could occur in the Humboldt Offshore Wind Power Project project area include the federally listed Chinook salmon (*Oncorhynchus tschawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), green sturgeon (*Acipenser medirostris*), and eulachon (*Thaleichthy spacificus*), and the state-listed longfin smelt (*Spirinchus thaleichthys*). Chinook and coho salmon, steelhead, and green sturgeon are likely to use the area briefly during part of their extensive migrations. Eulachon are also likely to occur at depths similar to those found in the project area (Sweetnam et al. 2001). Information on the marine distribution of longfin smelt is scant (CDFG 2009); however, since the project is located outside of state waters, the state has no jurisdiction.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for ecosystem interactions should be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Humboldt Offshore Wind Power Project.

Scientific Thresholds

Baseline and effects monitoring should detect if the following scientific threshold is exceeded for ecosystem interactions that could occur in the Humboldt Offshore Wind Power

Project area: underwater hard structures attract different fish and invertebrate species than pre-project conditions that result in modifying species assemblages or food webs.

Regulatory Thresholds

Baseline and effects monitoring should also determine if one of the following two regulatory thresholds is exceeded for fish and their habitats that could occur in Humboldt Offshore Wind Power Project area:

1. For all fish and invertebrate species listed as federally threatened or endangered, the threshold is to kill, harass, or injure one individual. For fish and invertebrate species listed by the State of California as threatened or endangered, the threshold is to kill one individual. In the project area, federally listed fish species include the Chinook salmon, coho salmon, steelhead, green sturgeon, and eulachon; state-listed fish species include coho salmon and longfin smelt, although longfin smelt would not be considered because the project is located outside of state waters.
2. Essential fish habitat (EFH) (including Habitat Areas of Particular Concern) could be adversely affected by the project (e.g., adverse effects are impacts from the project that decrease the quality and/or quantity of EFH; see 67FR2343 for further explanation). In the project area, EFH has been designated for many fish species, notably rockfishes and other groundfish, highly migratory fishes, and coastal pelagic species.

Step 6: Baseline Information Monitoring Needs

There is very little information about the diel, seasonal and interannual distribution patterns, and feeding, spawning, or nursery habitats of fish in the Humboldt Offshore Wind Power Project area. This information would help to determine which fish species use the project area and the extent to which they do so.

Step 7: Effects Monitoring Information Needs

There is little or no existing information about effects of hard structure on fish and ecosystem interactions in temperate offshore areas such as the Humboldt Offshore Wind Power Project area, including either attraction or avoidance behaviors. To evaluate the effect of static devices on fish and invertebrates in the project area, information about their distribution, habitat associations, behaviors, and food habits should be collected and evaluated.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

To collect baseline information about fish and invertebrates that may occur in the vicinity of an offshore wind installation, several of the following techniques can be used to determine diel, seasonal and interannual distribution patterns, and habitat associations of fish and invertebrates.

- **Trapping.** Trapping can be used to evaluate presence, density, size, and temporal distribution of epibenthic invertebrates and some fish species. Trapping is routinely used by commercial fishers of Dungeness crab; traps can be modified to catch smaller crabs (smaller than legally mandated catch size; Terrill et al. 2010).

To be most effective, trap bait, soak time, and trap configurations should be evaluated in a pilot effort and power analysis conducted to determine level of effort (Terrill et al. 2010).

- **Bottom and Mid-Water Trawls.** Bottom trawling using beam trawls or otter/shrimp trawls can be very effective for inventory of bottom fish and epibenthic invertebrates. Mid-water trawls can provide information on pelagic organisms (Arimitsu et al. 2003; Lindeboom et al. 2001); including density (fish/unit area or volume swept; Terrill et al. 2010; Trippel 2011; Davies et al. 2001; Curtis and Coggen 2007; Lindeboom et al. 2011; Arimitsu et al. 2003).
- **Mobile and Stationary Hydroacoustic Surveys.** Pelagic fish and invertebrates and biomass, including scyphozoan jellies that are important prey for leatherback turtles, can be evaluated using mobile or stationary hydroacoustic surveys (Graham 2009; Parker-Stetter et al. 2009; Taylor and Maxwell 2007; Georgakarakos and Kitsiou 2008; Trenkel et al. 2008; Lindeboom et al. 2011). Mobile hydroacoustics can be used to evaluate the spatial distribution of species at a point in time, whereas stationary hydroacoustics can be deployed at fixed locations to monitor sites over time (Wilson et al. 2003). Types of hydroacoustic equipment include single-frequency and multichannel-frequency echosounders and acoustic cameras. Single-frequency echosounders are traditionally used to locate fish and to determine relative densities. Use of multichannel frequencies improves fish density estimates and can also identify species in some instances (for example, where there are few species) because each fish species has unique acoustic responses in part related to size. Acoustic cameras convert sound pulses into digital images/video and are used mostly for enumerating species in low-visibility water conditions.
- **Purse Seines, Multi-Mesh Gill Nets, Hook and Line.** Because hydroacoustic surveys cannot accurately identify pelagic fish and invertebrates to species, unless the choices are few and size differences among species is large, methods such as multi-mesh gill-nets (Boldt and Haldorson 2002; Duffy and Beauchamp 2008), purse seines (Taylor and Maxwell 2007), and hook-and line-sampling (Starr et al. 2010) can be used to validate species identification and to provide specimens for evaluation of food habits or condition.
- **Visual Surveys.** Demersal fish and epibenthic invertebrate presence, density, size, and temporal distribution can be ascertained using visual survey methods, such as diver-operated video transects, towed video transects using sled-mounted cameras, and ROV transects or drop-camera surveys (Somerton and Glendhill 2005; Love et al. 2009; Yoklavich and O'Connell 2008; Martin and Lowe 2010; Pacunski et al. 2008; Coggen et al. 2007; Shortis et al. 2007).
- **Acoustic Telemetry.** Migratory listed fish are best evaluated using telemetry (Lindley et al. 2008; Erickson and Hightower 2007; Payne et al. 2010; Block et al. 2011). Telemetry can be used to examine the movements and behavior of individual fish to determine if they are using the project area for migration or are attracted to or avoiding the project area. Because of the large number of researchers now tagging fish with acoustic tags (e.g., Lindley et al. 2008; Payne et

al. 2010), acoustic receivers are the likely choice for monitoring at projects. However, other approaches (satellite, archival tags) are being used, primarily for larger animals (including sharks, tunas) with longer migrations. Acoustic tags are currently being used with green sturgeon and some elasmobranchs (e.g., great white sharks *Carcharodon carcharias*); battery power is related to tag size, so larger fish can take larger tags with longer battery life (years). Smaller fish (salmon smolts) can also have acoustic tags implanted in them, but the life span of small tags is usually very short (weeks, months). Acoustic telemetry can provide information on species presence and time spent in the vicinity of the receiver.

Study Design for Baseline Monitoring of Fish and Invertebrates

In general, surveys should ideally provide baseline information for the project area on 1) timing and life stages of species present, 2) species and their habitat associations, and 3) species abundance. Monitoring should be informed by existing information, including commercial and recreational fisheries and satellite or acoustic telemetry.

Survey design should be based on knowledge of the species and their behaviors, either through pilot studies or existing information; for example, diel patterns in fish behavior may make it important to survey at night or at dawn/dusk (Taylor and Maxwell 2007). To determine the level of effort needed (e.g., frequency and intensity of sampling, stratification of habitat, number of replicates per stratum), power analyses should be performed on the data collected during pilot efforts or the first survey(s) (Terrill et al. 2010; Pitcher et al. 2009; Peterman 1990; Taylor and Maxwell 2007). Power analysis should also address the range of effect sizes as well because small effects may be important to regulatory agencies. However, important to consider is that the level of effort necessary to detect small effects may not be feasible. Variables such as water column temperature and salinity, dissolved oxygen, chlorophyll concentration, and depth should also be recorded during surveys; these can serve as explanatory variables of abundance and distribution and increase the statistical power of detecting change.

Surveys would be conducted for a minimum of 1 year prior to installation of wind turbines if existing baseline data are not sufficient to meet the requirements of the permitting agencies. However, it is not necessary to conduct pre-project surveys to detect a population-level change if an adequate number of control sites are also surveyed along with the project area (Underwood 1994; Martins et al. 2009). The effect of mooring lines post-installation on feasibility of survey techniques needs to be considered: if the survey technique cannot be conducted because of interference with mooring lines after installation, it should not be used in a BACI design. The project area and two or more areas of identical size and with similar oceanographic characteristics (i.e., similar depth, distance from shore, bottom substrate, water quality, proximity to upwelling fronts) outside the project area would be surveyed as the control sites (Underwood 1994; Martins et al. 2009). Surveys should be conducted during different times of day and night, and at different times of the year in order to incorporate diel and seasonal distribution patterns of fish and invertebrates. Changes to ocean regimes need to also be considered; monitoring should include El Niño and La Niña regimes because species composition is likely to change.

- **Transect-Based Surveys.** Bottom trawls, mid-water trawls, visual surveys conducted by divers or divers with video cameras, ROVs, sled-mounted cameras, and mobile hydroacoustic surveys all could be employed in transects of the study area. A combination of some or all of these methods would be conducted with the objectives of 1) detecting spatial and temporal distribution patterns and habitat associations of fish and invertebrate species in the project area; 2) providing baseline to evaluate changes in density of fish species in the project area; and 3) providing baseline to evaluate changes to species assemblages in the project area.

- **Stationary Surveys.** Acoustic telemetry, stationary hydroacoustic surveys, trapping, multi-mesh gill nets, hook-and-line sampling, purse seines, and visual surveys using drop-cameras or baited video can be used to obtain information on species composition and use of the project area. A combination of some or all of these methods could be utilized.

Protocols That Need Development/Testing

Using combinations of gear or methods to detect, categorize, and enumerate pelagic fish, invertebrate, sea turtles, and marine mammal species at a project site using stationary and mobile acoustic and trawling surveys is under development by University of Washington (funded by BOEM) to determine how well each technology captures spatiotemporal variation in nekton density distributions. Acoustic-optical systems are being developed that combine both acoustics and optical instrumentation to provide information on fish communities with verification of targets (fish species; Ryan et al. 2009). Passive acoustic monitoring can detect presence of species that produce sound and is under further development (Širović et al. 2009). Autonomous underwater vehicles that include mounts for acoustic, oceanographic, visual, and telemetry monitoring are becoming more commonplace for characterizing nektonic communities and habitat conditions (Fernandes et al. 2003).

Selecting a Protocol for Baseline Monitoring of Fish and Invertebrates for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of survey techniques. Some survey techniques may have the statistical power to detect very large changes only (Pitcher et al. 2009). The location and specifics of the project site, such as depth, distance to reefs/hard structure, and fishing activities are also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-4 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed.

All baseline transect-based surveys would be conducted in the project area and in one or two control areas for at least 1 year prior to installation of the wind turbines. Because the project site spans depths of 70–180 m, effort should be stratified by depth (Trippel 2011) or bottom habitat that is, changes in substrate composition.

Table 7-4 Advantages and Disadvantages of Survey Techniques for Baseline Monitoring of Fish and Invertebrates.

Technique	Advantages	Disadvantages
Trapping	• Species "in hand" and can be identified and used to evaluate condition (weight, length, food habits), or tagged and released • Suitable method for pilot or commercial scale projects • Feasible for any site accessible by boat, best for soft substrates • Can be conducted day or night • Likely can be conducted before and after wind turbine installation	• Traps are size and species selective, e.g., if species not attracted to bait they won't be trapped • Predation of trapped animals (i.e., by larger trapped animals) can occur • Gear susceptible to being lost and may not be feasible at project site after turbine installation due to mooring lines and anchors.
Bottom Trawls and Mid-water Trawls	• Species "in hand" and can be identified and used to evaluate condition (weight, length, food habits, age). • Suitable method for pilot or commercial scale projects • Bottom trawls feasible at soft-bottom site • Can be conducted day or night	• Can be conducted before wind turbine installation but would be feasible post-installation only where there are no mooring lines and anchors • Trawls are size-selective and some species can avoid them easily, depending on speed of tow • Small capture range, requires high effort (frequency/ intensity of sampling) for species that are patchily distributed
Purse Seine, Multi-mesh Gill Nets, Hook and Line Sampling	• Can be used to ground-truth hydroacoustics survey data • Species "in hand" and can be identified and used to evaluate condition (weight, length, food habits, age), and with hook & line potentially tagged and released • Suitable method for pilot or commercial scale projects • Multi-mesh gill net panel mesh can be sized to capture fish of different sizes and can sample specific depths (e.g., bottom, midwater, surface); can use on rocky substrate • Can be conducted day or night • Hook and line sampling effective for rockfishes and many species likely to be attracted to hard substrate on the bottom, and can use on rocky substrate	• Nets and purse seines may not be feasible post-installation due to mooring lines and anchors • Hook and line sampling is species selective and may require significant effort to detect rare species. • Small capture range • Multi-mesh gill nets (where large mesh sizes are included) can have unintended bycatch of seabirds and marine mammals; soak times can mitigate for bycatch but if too short may not be sufficient to capture fish

Table 7-4 Advantages and Disadvantages of Survey Techniques for Baseline Monitoring of Fish and Invertebrates (continued).

Mobile and Stationary Hydroacoustic Surveys	• Provides information on fish and nektonic invertebrate temporal and spatial distribution and abundance/biomass • Can provide limited information on species composition and fish size • Suitable method for pilot or commercial scale projects • Large detection range, non-invasive • Likely minimal behavioral disturbance • Stationary hydroacoustics provides information at a site over time, mobile surveys provide snapshots of information over large spatial scales • Provides depth-specific information on fish distribution, both in the water column and near the bottom • Can use on soft or hard bottom	• Fish not “in hand”, therefore species identification and condition information not available without ground-truthing • Duty-cycles for stationary hydroacoustic surveys are limited unless cabled observation is possible.
Visual Surveys using ROV/towed camera or divers	• Provides information about species distribution and abundance (line transect), estimate of size (especially if used with laser or other reference) • Can provide a permanent observation record (video or photograph) for later analysis • Suitable method for pilot or commercial scale projects • Feasible at any site accessible by boat • Can use at depths greater than diver survey • Can survey day or night • Best for species suspected or known to occur regularly in the project area • ROV can be set up with lasers or other means to evaluate fish size	• Requires sufficient visibility (light, clarity) to discern fish species and numbers • Species not “in hand”, so condition information (other than size estimation) not possible • Some species may actively avoid bottom disturbance by gear, some may be attracted • Small range of detection • Artificial lights and ROV motor noise may affect behavior • Diver surveys have potential for diver observation bias, and are limited to relatively shallow depths compared to towed camera or ROV surveys

	• Divers can observe important habitat features and can survey both before and after project installation • Can use on soft or hard bottom	
Acoustic Telemetry	• Provides detailed tracking information of individual fish movement • Suitable method for pilot or commercial scale projects • Feasible at any site because fish are tracked remotely • Best for species suspected or known to occur regularly in the project area • Used for larger and wide-ranging fish (i.e., green sturgeon) • Monitoring for presence 24/7 • Can provide information on behavior, e.g., residence time	• Does not provide information about fish abundance, distribution, or species composition • Short transmitter battery life (~4+ months) limits ability to evaluate small fish (150–300 mm in length) • Capture of fish and transmitter implanting is invasive and may affect fish behavior and health, especially smaller fish • Depends on other researchers implanting acoustics tags, numbers of fish tagged are likely to be low

The selected protocol for evaluating baseline demersal fish and epibenthic invertebrate distribution for the Humboldt Offshore Wind Power Project would likely be visual surveys using ROV transects because this technique is cost-effective, can likely be used after installation of the wind turbines, and should yield sufficient information about the distribution of bottom-dwelling species in the project area. However, because water clarity can affect detection distance, pilot efforts will need to be conducted to evaluate ROV effectiveness. Pilot ROV surveys could deploy both a visual and acoustic camera and compare results; the acoustic camera is able to "see" targets in conditions that optical methods may not. ROV transects could also inform sampling design (stratification) for trawl surveys by providing information on habitat types in the project area. Trawl surveys would be conducted concurrently with ROV surveys to corroborate species identification and provide additional information on fish condition—size or food habits in the project and control areas, for example. It may not be possible to trawl post-installation due to potential for interaction with moorings, so corroborating ROV findings with trawl survey information pre-project could provide useful information. Trawl and ROV surveys should ideally be conducted both day and night.

For trawling and ROV surveys, a random stratified design should be used with depth strata based on existing information, e.g., depth distribution of key species likely to be in the project area from management plans (McCain et al. 2005) or from pilot survey data. Initially, at least three or more trawl tows/ROV transects should be conducted at randomly selected depths within each depth stratum in the project area and in each of the control areas, and each tow/transect would be the same approximate distance (or time, assuming boat speed is the constant) and approximately the same depth (e.g., towing along isobaths not across). Ultimately, power analysis of first survey results would be used to set the level of effort needed in subsequent surveys (number of tows/stratum, tow length/duration). Surveys of the project area and at each of the control areas would be conducted several times throughout each year to evaluate seasonality and each survey of project area and control sites would be conducted as close in time as possible. Comparison of fish and epibenthic invertebrate species composition and densities at the project area and control areas before and after installation would provide information to evaluate if the scientific and regulatory thresholds may have been exceeded.

Acoustic receivers would also be deployed in the project area to detect presence of tagged fish, placed in a line perpendicular to shore within the project area, with receivers spaced no more than 400 m apart (Payne et al. 2010; Domeier 2005). If possible, a full year of deployment is preferable, although deployments could be more focused on specific times of year when species of concern are more likely to be present (e.g., green sturgeon). It is assumed that baseline monitoring will not include tagging fish but only detection of fish already tagged by other organizations.

Pelagic fish and invertebrate distribution and biomass would be evaluated using mobile hydroacoustic surveys in the project area only, to evaluate diel and seasonal distribution patterns and target sizes at the project site, to be compared later to post-installation hydroacoustic monitoring. Like ROV and trawl surveys, sampling should occur several times per year to consider seasonality but also could be conducted day and night to evaluate diel distribution patterns. Mobile hydroacoustic surveys would be conducted using transects (Parker-Stetter et al. 2009; Taylor and Maxwell 2007; Wilson et al. 2003). To ground-truth hydroacoustic surveys, multi-mesh gill nets could be deployed in short soaks to corroborate species identification and sizes. Multi-mesh gill nets are preferable to trawls or purse seines, which may not be useable post-installation (see Table 7-4).

Step 9: Effects Monitoring Protocols

Existing Sampling Tools

In order to assess the potential effects of wind energy projects on ecosystem interactions, including FAD and artificial reef effects, hydroacoustic and visual survey methods can be a cost-effective way to evaluate if species (targets) occur at the anchors, mooring lines, or the hull/platform. Mooring lines may interfere with certain types of gear (towed trawls, purse seines, traps, ROV when currents are strong) and may make their use infeasible. Hydroacoustic survey methods can detect “targets”, but species identification can be difficult, while visual survey methods and fish sampling with multi-mesh gill nets, hook and line, trawls, and trapping can be used to help determine size/species of fish, and captured specimens can provide a basis for evaluating food habits and condition (e.g., age, reproductive status). See Step 8 for a description of these existing survey techniques.

Study Design for Monitoring Effects on Seabirds

Monitoring protocols used in baseline studies may be repeated using a BACI design or After-Control-Impact (ACI) design (Martins et al. 2009; Pitcher et al. 2009) in order to evaluate species assemblages and densities pre- and/or post-installation. A number of control sites (two or more) would be warranted, especially for ACI designs. Methods could include any of the transect-based survey techniques (trawls, ROV/towed camera surveys, mobile hydroacoustics), and stationary surveys (acoustic telemetry, hydroacoustics). See Step 8 for a description of these techniques.

- **Reef effect.** Use of the project's hard structures on or near the bottom by fish and invertebrates can be evaluated using hydroacoustic surveys but will likely require ground-truthing with methods such as hook and line, trapping, or multi-mesh gill nets. Mobile or stationary hydroacoustic surveys can be used to detect fish associated with bottom structure (Doray et al. 2008; Wilson et al. 2003). Mobile hydroacoustics may be preferable to stationary hydroacoustics until targets are observed. Individuals and biomass can be evaluated using hydroacoustic surveys, and once targets are observed (it may take some time for species to use the new hard structure habitat) other methods can be used to ground-truth the targets. Species composition and relative abundance of hydroacoustic targets can be evaluated and ground-truthed with visual surveys (camera/video surveys with ROV, SCUBA if shallow, submersibles, baited video; Wilhelmsson et al. 2006; Dempster 2004; Shortis et al. 2007), as well as hook and line, trapping, and multi-mesh gill nets, which can provide specimens for further information on food habits and condition (e.g. weight, size).
- **FAD effect.** Use of the project platform and mooring lines by fish and invertebrates (i.e., jellyfish polyps) attracted to underwater structure could be evaluated using mobile or stationary hydroacoustic surveys (see Doray et al. 2008 for evaluating fish at FADs; Wilson et al. 2003 for fish at oil platforms; Lo et al. 2008, Holst and Jarms 2006, and Hoover and Purcell 2008 for jellyfish polyps at artificial structures), visual surveys, multi-mesh gill nets, mid-water trawls, purse seines, and acoustic telemetry. Fish may not be attracted to the structure for some time, so using cost-effective methods to find targets/biomass should occur before ground-truthing the hydroacoustic targets. Ground-truthing of hydroacoustic survey data can be conducted with visual surveys (ROV), as well as multi-mesh gill nets, and mid-water trawls and purse seines (if possible around mooring lines). Evaluating behavior such as residency time for larger species, such as green sturgeon, adult salmon, and sharks could be done with acoustic telemetry. Persistent presence of highly visible predators (marine mammals, birds) can also indicate FAD effect.
- **Changes to distribution and abundance of soft-bottom fish and epibenthic invertebrates.** Trapping and bottom trawling can be used to evaluate changes to demersal fish species assemblages and densities, although mooring lines and anchors may not make these methods feasible. Visual surveys (diver/diver operated video, towed video, ROV, submersible) may also be used to evaluate bottom species; however, mooring lines and anchors could also make it infeasible to use some of these methods, especially in stronger currents.
- **Evaluate gut contents of piscivorous fish to determine diet, including predation on listed fish species.** The gut contents of piscivorous fish captured in trawls, traps, multi-mesh gill nets, and other methods that provide fish specimens,

can be examined to evaluate changes in food habits (Nairn et al. 2004; Jaquemet et al. 2011; Boldt and Haldorson 2002; Duffy and Beauchamp 2008).

Protocols That Need Development/Testing

See Step 8 for a description of protocols that need further development or testing.

Selecting a Protocol for Effects Monitoring of Seabirds for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may only have the statistical power to detect change at the commercial scale. The project moorings could interfere with many of the techniques and needs to be considered before baseline sampling is conducted, if a BACI design is used the survey methods should be consistent before and after installation. For FAD and artificial reef effects, ACI design is preferable. The location and specifics of the project site, such as bottom type (hard bottom versus soft) and typical sea conditions (e.g., sheltered or open ocean, strong currents), is also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-4 (see Step 8) identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed. Because the different techniques provide different but limited types of information, several different techniques would be selected in order to provide a thorough evaluation of potential effects on ecosystem interactions.

The selected protocols for determining the effects of the Humboldt Offshore Wind Power Project on ecosystem interactions includes methods to evaluate artificial reef and FAD effects: stationary hydroacoustic surveys using mobile split-beam echosounders would be conducted several times per year post-installation (to evaluate seasonal changes in distribution and abundance; Wilson et al. 2003). Stationary hydroacoustic survey equipment could be set at one or more platforms to evaluate changes over time at a fixed location (Wilson et al. 2003). Once targets are detected, visual surveys using ROV would be conducted to evaluate fish and invertebrate species at the platform, along the moorings and at the bottom to verify species identification. Mobile hydroacoustic and ROV surveys would also occur at one or more control sites. In addition to ROV surveys, hook-and-line or multi-mesh gill nets could be used to validate species identification and obtain further information on fish condition (weight) and as specimens for food habit assessment. Acoustic telemetry would be used to determine presence of fish and scyphozoan jellyfish and residence time in the project area, with receivers deployed either as described for the baseline surveys in a BACI type design or around the project footprint and at one or more control sites in an ACI design. Changes to distribution of demersal fish and invertebrates could be done with ROV at the project site and at control sites using a BACI design.

7.3 MOVING DEVICES AND BATS

Offshore Wind High Priority Interaction #3

Humboldt County, California

Stressor: Moving Devices

Receptor: Bats

Step 1: Description of Technology and Site/Location

This case study is based on offshore wind energy technology (Figure 7-1) that would be deployed in Humboldt County, California (Figure 7-2).

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Static Devices **Priority: High**

Issue: Bats could collide with wind turbines while flying through the area, or be injured or killed from barotrauma. Bats could also change their behaviors in response to wind turbines, by attraction to the turbines (increasing risk of collision).

Step 3: Spatial and Temporal Scale of Stressor

For the Humboldt Offshore Wind Power case study, the stressors are the wind turbines (moving devices) that could affect bats (receptor) in the project area. The three-dimensional footprint of the moving devices is as follows:

- Rotor Diameter 120–150 m
- Turbine Hub Height: 80–90 m
- Overall Height: 140–165 m
- Generating capacity: ±6 MW with a cut-in wind speed of approximately 4 m/s
- Distance between each wind turbine: 1 km
- Array footprint for 25 turbines: 24 km^2
- Array will be 8 km long in an east–west orientation x 3 km wide

The temporal scale of the stressors is the duration of the project.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to conduct an effects analysis, it is necessary to determine the overlap between bats (receptor) and moving devices (stressor). To assess baseline conditions in the project area and assist with determining potential effects of the stressors on bats, the first step is to assemble all available information on the following distribution and behavior characteristics: proximity of breeding colonies to the stressor; the location of the stressor in relation to potential flight lines between principal land masses and islands; seasonal distribution; attraction behaviors to the turbines; flight pathways and timing; and flight characteristics such as flight height, and speed.

Bat distribution information specific to the vicinity of the Humboldt Offshore Wind Power Project project area is extremely limited. Bats are expected to be rare but most likely to occur in the project area during fall migration. There are a number of bat species known to roost and breed in redwood coastal forests along the north coast of California (Gellman and Zielinski 1996); however, these species are less likely to occur offshore than the migratory tree roosting bat species (hoary bat, western red bat, and silver-haired bat) that make seasonal migrations in North America in late summer and early fall (Cryan and Brown 2007). In the fall of every year, hoary bats, and occasionally other bat species, are observed roosting in trees, vegetation, buildings, and rock outcrops on Southeast Farallon Island, 48 km west of San Francisco (Cryan and Brown 2007). Their consistent presence that far offshore in fall indicates that migratory tree roosting bats are capable of making long distance flights over water during migration and are likely attracted to offshore islands and/or anthropogenic structures (which could include offshore wind turbines) for roosting (Cryan and Brown 2007). However, the project area is not located between any land masses or islands with suitable roosting habitat; thus bats may be less likely to stop over the project area during migration. They more commonly arrive at Southeast Farallon Island on nights with low winds and barometric pressure, and following overcast nights (Cryan and Brown 2007). They fly lower in early evening and early morning when transitioning between roosting and migration, and they generally forage at altitudes of less than 125 m. Over land, migrating bats fly at altitudes of greater than 400 m (Kunz et al. 2007), but in Scandinavia, less than 10 m.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for bats should be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Humboldt Offshore Wind Power Project.

Scientific Thresholds

Baseline and effects monitoring should detect if one of the following two scientific thresholds are exceeded for bat species that could occur in the Humboldt Offshore Wind Power Project area:

1. Strikes with turbines or support towers causing or contributing to population declines; or
2. Significant proportion of population being directly killed or injured by strikes with turbines or support towers, or indirectly by altering behavior (avoidance of turbines or attraction to towers or lighting)

The bat species that could occur in the project area include the hoary bat (*Lasiuruscinereus*), silver-haired bat (*Lasionycteris noctivagans*), and western red bat (*Lasiurus blossevillii*).

Regulatory Thresholds

Baseline and effects monitoring should also determine if the following regulatory threshold is exceeded for bat species listed as federally threatened or endangered that could occur in the

Humboldt Offshore Wind Power Project area: to kill, harass, or injure one individual. However, there are no federally or state-listed bat species that could occur in the project area.

Step 6: Baseline Information Monitoring Needs

Existing information about bat flight pathways, timing, flight characteristics, and how they are influenced by weather conditions is lacking for the Humboldt Offshore Wind Power Project area. This information would help determine to what extent bats use the project area.

Step 7: Effects Monitoring Information Needs

Existing information about bat flight pathways, timing, flight characteristics, and how they are influenced by in the Humboldt Offshore Wind Power Project area is lacking. To evaluate the effect of moving devices on bats in the project area, information about daily flight pathways, flight altitude, and attraction behaviors should be collected and used to model potential encounter and collision rates of bats with the wind turbines.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

In order to collect baseline information about bats that may occur in the vicinity of an offshore wind installation, a combination of the following monitoring protocols could be used. Each of these techniques has its own strengths, limitations, and biases, and generally a combination of techniques is needed (Kunz et al. 2007). Acoustic detection of bats can be used to monitor for bat presence, activity, and relative abundance, while night-vision observations can be used to view flight behavior, direction, altitude, and response to turbines (Gauthreaux and Livingston 2006; Kunz et al. 2007; Rodrigues et al. 2008). Marine radar detects the trajectories of flying bats but separating them from similarly sized birds is not possible; night-vision observations can be used to validate data collected with marine radar and help determine size/species of bats, distinguish bats from birds, and detect collisions with turbines (Gauthreaux and Livingston 2006; Hüppop et al. 2006; Kunz et al. 2007). Data from these techniques can be used to assess flight characteristics (i.e., altitude, speed, direction) and model collision risk.

- **Acoustic Monitoring.** Echolocating bats emit ultrasonic vocalizations that can be monitored with a microphone and detector-recorder system. The system can either translate the acquired ultrasonic signals into humanly audible tones for manual monitoring, or convert ultrasonic signals into digital data for storage and processing (Kunz et al. 2007). To collect baseline data on bats in the project area, ultrasonic detectors can be deployed on a boat or platform (Sjollema 2010). Bats can often be identified to species or species groups using this method (Sjollema 2010).
- **Night-Vision Observations.** Night-vision goggles, cameras, scopes, powerful spotlights, reflective infrared cameras, and/or thermal imagery cameras can be used to observe flight behavior, direction, altitude, and response to turbines (Gauthreaux and Livingston 2006; Kunz et al. 2007; Rodrigues et al. 2008). Night-vision goggles can identify birds and bats in flight ≤ 150 m (Kunz et al. 2007). Spotlights can also be used to view insects around the wind turbines to determine if they could be attracting bats to the rotor-swept zone (Ahlén et al. 2009). Observations could

also be used to validate radar data and distinguish birds from bats, although species identification is rarely possible (Kunz et al. 2007). These methods are generally not conducted remotely, necessitating an on-site observer.

- **Marine Radar.** Flight characteristics (i.e., altitude, speed, direction) and migration routes can be monitored with marine radar (Kunz et al. 2007). Two radars can be mounted as follows: horizontally mounted radar which maps the trajectories of flying bats and birds (targets) in time and space, and vertically mounted scanning radar which measures the altitude that targets are flying (Kunz et al. 2007). Marine radar is generally used for large-scale observations; the detection range for marine radar varies but is generally too large to distinguish between birds and bats (Kunz et al. 2007). Validation of targets should be conducted using night-vision observations (Kunz et al. 2007). Protocols for this technique are described in Desholm et al. (2004) and Geo-Marine, Inc. (2004); although these documents are describing protocols for monitoring birds, images derived from marine radar include bats (Gauthreaux and Livingston 2006). This method is generally more widely used for terrestrial wind installations and needs further testing and refinement for offshore wind installations, especially for bats (Rodrigues et al. 2008).

Study Design for Baseline Monitoring of Bats

Acoustic Monitoring. During baseline monitoring, acoustic monitoring would be conducted by an observer from a platform, boat, or ship in the project area (Rodrigues et al. 2008; Sjollema 2010). Acoustic monitoring could also be conducted from land if the project area is close to shore and/or if there is a landmark where bats might leave in the direction of a planned offshore wind farm (Rodrigues et al. 2008). An automated acoustic monitoring device could be used if a platform or land is in the project area. Surveys may be conducted throughout the year to capture seasonal variability, but effort should be increased during spring and fall migration. Acoustic monitoring from a boat would provide information about bat presence and activity in the study area, but may not determine bat activity at the height of the rotor-swept zone (depending on the height of the boat or ship). Acoustic monitors can help identify bats to species, but for most bat species, the detection range of acoustic monitors is $\leq$ 30 m, and for a few species it is only 3–5 m (Kunz et al. 2007). Detectability can be reduced by weather or environmental variables (Kunz et al. 2007); thus detection range could be reduced at sea and should be tested in the project area. Weather conditions, such as barometric pressure, wind speed and direction, precipitation, and moon phase should also be recorded during surveys; these can serve as explanatory variables of bat presence and activity.

Night-Vision Observations. Night-vision observations could be conducted from a platform, boat, or ship in the project area in conjunction with acoustic monitoring. Observations could also be conducted from land if the project area is close to shore and/or if there is a landmark where bats might leave in the direction of a planned offshore wind farm (Rodrigues et al. 2008). Surveys may be conducted throughout the year to capture seasonal variability, but effort should be increased during spring and fall migration. Surveys would be conducted during the year prior to installation of the wind turbines if existing baseline data are not sufficient to meet the requirements of the permitting agencies. This method could fail to detect bats if they are rare in the project area and should not be used to confirm absence of bats, and may be more useful for projects closer to land or where bats are known to occur regularly.

Marine Radar. Radar surveys would be conducted for a minimum of 1 year prior to installation of wind turbines, if existing baseline data are not sufficient to meet the requirements of the permitting agencies, and if a stable platform (e.g., anchored boat/ship) for mounting equipment can be achieved. Radar would likely be conducted to collect baseline information on both bats and birds, and would need to be validated using acoustic monitoring and/or night-vision observations. Surveys would be conducted throughout the year to capture seasonal variability, but effort should ideally be increased during spring and fall migration.

Protocols That Need Development/Testing

Due to the harsh ocean environment, site accessibility issues, and other challenges, acoustic monitoring for bats is not a widely used technique for detecting bats in offshore locations. However, Sjollema (2010) successfully collected offshore bat call sequences that were identified to species. Normandeau Associates (through funding awarded by BOEM) is currently developing an acoustic/thermographic detection protocol for offshore wind installations for both bats and birds. Regulatory agencies are likely to recommend a revised protocol for offshore wind installations in the United States.

Radar is not a widely used technique for monitoring bats in offshore locations or for investigating bat migration patterns due to the significant challenge of distinguishing between bats and birds, identifying species and individuals, and obtaining a stable platform for mounting. These techniques would require significant refinement and testing to be widely used as a monitoring protocol for offshore wind installations (Rodrigues et al. 2008).

Selecting a Protocol for Baseline Monitoring of Bats for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may only have the statistical power to detect change at the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean or open ocean), is also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-5 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed.

The selected protocol for baseline monitoring for the Humboldt Offshore Wind Power Project would be acoustic monitoring and night-vision observations from a boat during fall. Surveys would be conducted during the fall migration period when collisions with wind turbines are most prevalent (Cryan and Brown 2007). It would not be feasible to conduct radar and thermal imagery surveys prior to installation of the wind turbines because of the lack of a stable platform and the high seas that often occur in the project area.

Table 7-5 Advantages and Disadvantages of Monitoring Techniques for Baseline Monitoring of Bats.

Technique	Advantages	Disadvantages
Acoustic monitoring	• Devices can be automated and data recorded continuously • Can usually identify bats to species • Suitable method for pilot or commercial scale projects • Devices are relatively inexpensive and easy to use	• Detection range of each device is ≤ 30 m, could be less at sea due to waves/wind noise (Kunz et al. 2007) • Can only be used to assess presence and relative abundance of bats, does not provide detailed information about foraging behavior or flight characteristics • Can be used to determine if bats are foraging over open ocean or turbines
Night-vision observations	• Can be used to view bat behavior and flight directly, estimate flight height and direction, view collisions with turbines, and determine if insects are attracted to turbines • Observations can be conducted from a boat, platform, or from land • Suitable method for pilot or commercial scale projects • Could also be used to view behavior and flight of nocturnal seabirds	• Species identification rarely possible • Cannot be used to confirm absence of bats, may fail to detect bats if they are rare or require extensive survey effort • Ability to view bats impaired by rain and fog • Powerful spotlights used to view bats can affect behavior of bats/seabirds • Most night-vision viewing equipment cannot be automated or operated remotely and must be conducted by an observer • Labor intensive and expensive • Thermal imagery camera requires stable platform for equipment (i.e., a ship anchored in calm seas, a jack-up lift boat, land, or platform) • Thermal imagery cameras expensive (>$30,000/camera in 2006), but costs are decreasing (Gauthreaux and Livingston 2006; Kunz et al. 2007)
Radar	• System can be automated and data recorded continuously • Birds can also be surveyed • Detects the trajectories of flying targets • Suitable method for pilot or commercial scale projects • Can measure the passage rates for targets over a given period of time	• Requires stable platform for equipment (i.e., ship anchored in calm seas, a jack-up lift boat, land, or platform) • Cannot detect collisions • Cannot distinguish between birds and bats • Ability to detect bats impaired by rain, fog, and waves

Step 9: Effects Monitoring Protocols

Existing Sampling Tools

In order to determine the potential effects of an offshore wind installation on bats, a combination of the following monitoring protocols could be used: acoustic monitoring, night-vision observations, and radar. Each of these techniques has its own strengths, limitations, and biases, and generally a combination of techniques is needed (Kunz et al. 2007).See Step 8 for a description of these techniques.

Study Design for Monitoring Effects on Bats

Acoustic Monitoring. After installation of the wind turbines, automated acoustic monitoring devices could be deployed on the wind turbine support poles, one lower on the support pole to detect foraging bats near the water's surface and one at the height of the rotor-swept zone (Kunz et al. 2007). If it is determined, through prior research or from baseline surveys, that bats are only present during migration periods (i.e., spring and/or fall), then post-installation surveys should be conducted during that time (Rodrigues et al. 2008). Acoustic monitors can help identify bats to species, but for most bat species, the detection range of acoustic monitors is $\leq$ 30 m, and for a few species it is only 3–5 m (Kunz et al. 2007). Detectability can be reduced by weather or environmental variables (Kunz et al. 2007); thus detection range could be reduced at sea and should be tested in the project area. Weather conditions, such as barometric pressure, wind speed and direction, precipitation, and moon phase should also be recorded during surveys; these can serve as explanatory variables of bat presence and activity.

Night-Vision Observations. Night-vision observations would be conducted from a platform, boat, or ship in the project area. Observations could also be conducted from land if the project area is close to shore and/or if there is a landmark where bats might leave in the direction of a planned offshore wind farm (Rodrigues et al. 2008). If it is determined, through prior research or from baseline surveys, that bats are only present during migration periods (i.e., spring and/or fall), then post-installation surveys should be conducted during that time (Rodrigues et al. 2008). This method could fail to detect bats if they are rare in the project area and should not be used to confirm absence of bats, and may be more useful for projects closer to land or where bats are known to occur regularly.

Marine Radar. Radar surveys would be conducted for a minimum of 1 year after installation of wind turbines. Radar would likely be conducted to collect baseline information on both bats and birds, and would need to be validated using acoustic monitoring and/or night-vision observations. If it is determined, through prior research or from baseline surveys, that bats are only present during migration periods (i.e., spring and/or fall), then post-installation surveys should be conducted during that time (Rodrigues et al. 2008). If sufficient data is able to be collected from radar surveys, such as distinguishing bats from birds and determining flight height, speed, and direction, this data could be used to model collision risk of bats (Desholm et al. 2006). The collision prediction model uses this information to predict the number of bats that would collide with the turbines or be exposed to barotrauma (internal injuries after being exposed to rapid pressure changes near the trailing edges and tips of moving blades) and the number of bats that would avoid (either by chance or by evasive actions) colliding with the turbines.

Protocols That Need Development/Testing

See Step 8 for a description of protocols that need further development or testing. In addition, the use of mechanical vibration sensors to detect collision events is a new potential approach but requires that vibrations from colliding bats can be detected from background turbine vibration and from collisions with birds (Desholm et al. 2006).

The Northwest National Marine Renewable Energy Centers at Oregon State University and University of Washington, with funding from the Department of Energy, are designing, testing, and deploying an integrated sensor array to continuously monitor interactions (including impacts) of birds and bats on blades, nacelles and towers of wind turbines using a synchronized array of sensors including accelerometers, visual and infrared spectrum cameras, and acoustic monitors. The monitoring system will be designed to run continuously and at several turbines in parallel, with remote access to recorded images and sensor data to quantify interactions, including collisions, and identify organisms involved to the lowest taxonomic grouping possible.

Selecting a Protocol for Effects Monitoring of Bats for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. Some monitoring techniques may only have the statistical power to detect change at the commercial scale. The location and specifics of the project site, such as distance to shore or nearby island and average sea state (i.e., calm sheltered ocean or open ocean), is also expected to have a significant influence on the type of monitoring that is feasible. To assist with deciding on the appropriate method for a particular project, Table 7-5 (see Step 8) identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed. Because the different techniques provide different but limited types of information, several different techniques may be selected in order to provide a thorough evaluation of potential effects on bats.

The selected protocol for effects monitoring for the Humboldt Offshore Wind Power Project would be acoustic monitoring using automated devices deployed on the wind turbines, and night-vision observations from a boat during the fall migration period when collisions with wind turbines are most prevalent (Cryan and Brown 2007). Radar could also be conducted, as it would likely be conducted to monitor seabird activity in the project area. The data collected from acoustic monitoring, night-vision observations, and potentially radar, could be used to model collision risk of bats (Desholm et al. 2006). This information can be used to determine if the scientific and regulatory thresholds are being exceeded by determining if the turbines may cause or contribute to bat population declines.

7.4 STATIC DEVICES/BOAT TRAFFIC AND SEA TURTLES

Offshore Wind High Priority Interaction #4

Humboldt County, California

Stressor: Static Devices and Boat Traffic

Receptor: Sea Turtles

Step 1: Description of Technology and Site/Location

This case study is based on offshore wind energy technology (Figure 7-1) that would be deployed in Humboldt County, California (Figure 7-2).

Step 2: Identify Priority Stressor-Receptor Interactions

Stressor: Static Devices Priority: Medium

Issue: Sea turtles could collide with structures and become entangled in mooring lines. Lost fishing gear in the marine environment could become entangled in the mooring lines, further increasing the likelihood that sea turtles will become entangled.

Stressor: Boat Traffic Priority: Medium

Issue: Boats used during construction and maintenance of wind turbines could collide with sea turtles.

Step 3: Spatial and Temporal Scale of Stressor

For the Humboldt Offshore Wind Power Project case study, the stressors are the underwater structures, including support poles, anchors, mooring lines, and foundations for the turbines (static devices) that could affect sea turtles (receptor) in the project area. All of the following areas would constitute the project footprint for static devices and sea turtles:

- Array footprint for 25 turbines: 24 km^2 area that is 8 km long in an east–west orientation and 3 km wide in a north–south orientation
- Distance between each wind turbine: 1 km
- Foundation hull draft approximately 20 m
- Mooring system includes four mooring lines per turbine, anchored with pre-laid drag embedment anchors

Boat traffic associated with the Humboldt Offshore Wind Power Project case study would include large vessels (i.e., > 25 m) involved in towing the wind turbines to the project site and installing them at the beginning of the project, smaller vessels (i.e., < 20 m) used in maintenance activities for the life of the project, and larger vessels used to decommission the wind turbines at the end of the project. Large vessels would travel at around 10 knots, and small vessels would travel at faster speeds, up to 21 knots. The project area for boat traffic would include all areas transited via boat from shore to and from the project site, for the life of the project.

Step 4: Preliminary Assessment of Overlap between Stressor and Receptor

In order to conduct an effects analysis, it is necessary to determine the overlap between sea turtles (receptor) and static devices and boat traffic (stressors). To assess baseline conditions in the project area and assist with determining potential effects of the stressors on sea turtles, the first step is to assemble all available information on the following distribution and behavior characteristics: proximity of breeding locations or colonies to the stressor; the annual and seasonal distribution of these species; and if any of the species exhibits avoidance or attraction behaviors to the underwater structures or boats.

The leatherback turtle is the only sea turtle species expected to occur in the Humboldt Offshore Wind Power Project area. There are no breeding locations or colonies anywhere near the project area, as this species' nesting grounds are on subtropical and tropical beaches. Leatherback turtles are expected to be extremely rare in the project area but are most likely to occur in summer and fall, during El Niño years when waters are warmer, and when/where their prey (jellyfish) are found (S. Benson, pers. comm.). They are not known to be attracted to underwater or surface structures. However, jellyfish polyps are attracted to underwater structures; this interaction is examined in Section 7.2.

Step 5: Scientific and Regulatory Thresholds

Baseline and effects monitoring for sea turtles should be designed to detect when scientific or regulatory thresholds are exceeded as a result of the Humboldt Offshore Wind Power Project.

Scientific Thresholds

Baseline and effects monitoring should detect if the following scientific threshold is exceeded for all sea turtle species that could occur in the Humboldt Offshore Wind Power Project area: collision or entanglement with underwater components causing or contributing to population declines. The leatherback turtle (*Dermochelys coriacea*) is the only sea turtle species that is expected to occur in the project area.

Regulatory Thresholds

Baseline and effects monitoring should also determine if one or both of the following regulatory thresholds are exceeded for federally threatened or endangered sea turtles or critical habitat that could occur in Humboldt Offshore Wind Power Project area:

1. to kill, harass, or injure one individual; or
2. to adversely modify critical habitat.

The leatherback turtle is the only federally listed sea turtle species that is expected to occur in the project area. There is no designated or proposed critical habitat for any sea turtles species within the project area.

Step 6: Baseline Information Monitoring Needs

There is limited existing information about the seasonal and interannual variability of sea turtle distribution in the Humboldt Offshore Wind Power Project area. This information would help determine the species of sea turtles, and the extent of use in the project area.

Step 7: Effects Monitoring Information Needs

It is unknown if sea turtles could be attracted and/or become entangled with the underwater structures or lost gear entangled in mooring lines associated with the Humboldt Offshore Wind Power Project, or if they will collide with boats used in installation and maintenance of wind turbines. It is also unknown if lost fishing gear would become entangled in the mooring lines, which could increase the likelihood that sea turtles become entangled in the underwater structures.

Step 8: Baseline Monitoring Protocols

Existing Sampling Tools

In order to collect baseline information about sea turtles that may occurring the vicinity of an offshore wind installation, one or more of the following monitoring techniques can be used to determine seasonal and interannual variability of sea turtles.

- **Aerial Surveys.** Sea turtles can be surveyed from a small, fixed-wing aircraft flying at about 200 m altitude at a cruising speed of 167–185 km/h (Benson et al. 2007). Transects would be established a minimum of 2 km apart. This standardized method has been used to estimate density and abundance of sea turtles, and can be employed in the project area. Sea turtle prey, which consists primarily of jellyfish, can also be detected using this method (Benson et al. 2007).
- **Satellite Tracking.** Satellite tracking is generally used to track long-distance migratory movements of sea turtles (e.g., Kobayashi et al. 2008; Benson et al. 2011), although this method has also been used to track shorter range movements (e.g., home range sizes on the order of 1000 km^2; Hart and Fujisaki 2011). Individual sea turtles are captured and fitted with satellite tags and tracked to determine coarse–scale fidelity to ocean habitats and to track migratory pathways (Kobayashi et al. 2008; Benson et al. 2011). Satellite tracking data can be merged with remotely sensed environmental data (i.e., chlorophyll concentration, sea surface temperature) to characterize pelagic habitat used by the sea turtles (Kobayashi et al. 2008). Location data of sea turtles with satellite transmitters is transmitted via satellite, enabling data recovery remotely.

Study Design for Baseline Monitoring of Sea Turtles

Aerial Surveys. Aerial surveys would be conducted with the goal of determining the density and abundance of sea turtles in the project area. Surveys would be conducted for a minimum of 1 year prior to installation of wind turbines if existing baseline data are not sufficient to meet the requirements of the permitting agencies. However, it is not necessary to conduct pre-project surveys to detect a population-level change, if an adequate number of control sites are also surveyed along with the project area (Underwood 1994; Martins et al. 2009). The project footprint and 2 or more areas of identical size and with similar oceanographic characteristics (i.e., similar depth, distance from shore, distance from frontal features, bottom substrate, and water quality) outside the project area would be surveyed as the control sites Underwood 1994; Martins et al. 2009). Surveys should be conducted throughout the year in order to assess seasonal variation of sea turtles. If it is determined that sea turtles are seasonally abundant, future surveys could be concentrated during the season when they are most abundant. For each survey, the entire study area should be surveyed in 1 day, if possible (Thaxter and Burton 2009).

Satellite Tracking. If it is determined, either through baseline aerial surveys or from existing information, that the project area is a high-use area for sea turtles, the movements of individual sea turtles could be tracked using satellite tracking. However, location error for satellite tags is high so tracking would only inform large-scale movements. In order to obtain sufficient data to assess key foraging areas, daily movements, and to account for potential transmitter loss or failure, a number of sea turtles (i.e., > 10) should be captured and fitted with transmitters. In addition, existing information from other satellite tracking studies could be used to inform sea turtle distribution in the region of the project.

Protocols That Need Development/Testing

High Definition Aerial Surveys have been used to survey and estimate density or relative abundance of seabirds and marine mammals. However, the use of this method for surveying sea turtles has not been described in existing protocols (Thaxter and Burton 2009; Mellor and Maher 2008). A small, fixed-wing aircraft flies at a minimum height of 450 m and surveys using high definition video imagery or still photographs to record seabirds and marine mammals below the aircraft. Images are processed and analyzed after flights are completed. A new high definition aerial survey monitoring protocol for seabirds, marine mammals, and sea turtles for offshore wind installations is currently being developed by Normandeau Associates through funding awarded by BOEM; this protocol should be developed in the near future, and is expected to determine whether the method is appropriate for surveying sea turtles.

Selecting a Protocol for Baseline Monitoring of Bats for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. To assist with deciding on the appropriate method for a particular project, Table 7-6 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of locations, is also addressed.

Table 7-6 Advantages and Disadvantages of Monitoring Techniques for Baseline Monitoring of Sea Turtles.

Technique	Advantage	Disadvantage
Aerial Surveys	• Surveys can be used to calculate sea turtle density • Will not disturb sea turtle behavior • Can be conducted before and after wind turbine installations, if safe to fly between turbines • Suitable method for pilot or commercial scale projects • Feasible at any site that is accessible by aircraft • Can also be used to survey marine mammals • Can also provide information on prey (e.g., jellyfish) near the water's surface	• Cannot survey at night, in high winds, or in fog • Potential for observer bias • To properly derive density estimates, an estimate of the proportion of sea turtles visible at the surface is needed: this usually requires telemetry studies that incorporate time-depth recorders. Data can be site-specific (i.e. data from another region may not be applicable to the area of inference).
Satellite Tracking	• Tracks individual sea turtles worldwide and provides detailed location and movement information • Satellite transmitters can be programmed to report locations 24 h/day with a shorter battery life/tracking duration, or duty-cycled (e.g., report every 1–3 days) to conserve battery life and increase tracking duration • Because data is recorded remotely, a large number of individual sea turtles can be tracked relatively easily • Provides information that may be suitable for pilot or commercial scale projects, regardless of project area size • Feasible at any site because sea turtles are tracked remotely • Could utilize tracking data of sea turtles tagged by other researchers • Useful method if sea turtles suspected or known to occur regularly in the region of the project	• Does not provide population-level information on sea turtle distribution or abundance • Capture of turtles and transmitter attachment is invasive and can affect behavior and health • Transmitter detection is dependent upon satellite location and availability and detection frequency could be limited in some areas • Argos location errors will require use of more expensive GPS transmitters if site-specific information is required

The selected protocol for evaluating sea turtle density and distribution for the Humboldt Offshore Wind Power Project would likely be aerial surveys. Due to the rarity of sea turtles along the northern California coast, surveys should be conducted in conjunction with marine mammal surveys (Benson et al. 2007), and possibly seabird surveys although seabird surveys are usually conducted at a lower altitude (Camphuysen et al. 2004). High definition aerial surveys could be selected instead of aerial surveys, if it is determined that the method can be used for sea turtles, as it is used to survey seabirds and marine mammals (Thaxter and Burton 2009).

Aerial surveys would be conducted in the project area and control sites at a minimum of one year prior to installation of the wind turbines if baseline information is required by the agencies, and then for at least 1 year after installation of wind turbines. Surveys would be conducted several times throughout the year, but survey effort would be increased in late summer and early fall when sea turtles are most abundant along the northern California coast (Benson et al. 2007). Sea turtle distribution would be compared between the project area and control areas. Sea turtle abundance and distribution information would help determine if the scientific and regulatory thresholds may have been exceeded, by determining if sea turtles are at risk of being killed or injured by underwater structures in the project area. Sea turtle abundance and distribution information could also be used to determine the risk of collision with boats in the project area.

Satellite tracking would not likely to be used for the Humboldt Offshore Wind Power Project because the leatherback turtle is expected to only rarely occur in the project area. If it is determined that sea turtles are using the project area more than expected (i.e., >10 sea turtles detected per year), a satellite tracking study could be conducted to evaluate the use of the project area and further assess risk to the species.

Step 9: Effects Monitoring Protocols

Existing Sampling Tools

In order to assess the potential effect of wind energy projects on sea turtles that may occurring the vicinity of an offshore wind installation, one or more of the following monitoring techniques can be used to determine seasonal and interannual variability of sea turtles or their prey.

- **Aerial Surveys, Satellite Tracking.** See Step 8 for a description of these techniques.
- **Acoustic Cameras.** Sea turtles could be surveyed using acoustic cameras deployed at the project site to determine if there are interactions with underwater structures. Cameras would be operated remotely and record continuously. Acoustic cameras are not limited by light or turbidity, and have a greater imaging distance, regardless of turbidity, than optical cameras: even so, the probability of detecting a sea turtle in the project area would be extremely low. Acoustic cameras can also detect fish and nektonic invertebrates, so they could also be used to view their interactions with underwater structures. See “Ecosystem Interactions Case Study Approach” for a description of this technique.

Visual surveys using ROV, divers, or video cameras may be used to view fish and invertebrates that occur in the project area (see "Ecosystem Interactions Case Study Approach"), and it is possible that jellyfish polyps (sea turtle prey) and potentially sea turtles could also be viewed with these methods. The probability of viewing a sea turtle using these techniques, especially where they are rare, is extremely low and should not be considered an effective method for assessing effects of the project on sea turtles. However, these techniques could occasionally provide useful information or detect sea turtle activity or prey (e.g., presence/absence of jellyfish polyps) in the project area.

All vessels associated with the construction, operations, maintenance, and decommissioning of offshore wind projects will likely be required to abide by the "Vessel Strike Avoidance Measures and Reporting for Mariners" in order to reduce the potential for vessel harassments or collisions with sea turtles and marine mammals (NMFS 2008). This is not a monitoring technique but rather a standard protocol for avoiding strikes with sea turtles and marine mammals. Baseline or effects monitoring would not be necessary if these avoidance measuring are followed. However, while following the protocol, observers could collect useful information about the distribution of sea turtles in the project area. The data collected on sea turtle use in the project area from aerial surveys and/or satellite tracking could be utilized along with data on the frequency and pathway of vessel traffic associated with construction, operations and maintenance, and decommissioning of the project, to model collision risks to sea turtles from vessels. This would help determine if the scientific and regulatory thresholds may have been exceeded, by determining if sea turtles are at risk of being killed or injured by vessels as a result of the project.

Study Design for Monitoring Effects on Bats

- **Aerial Surveys, Satellite Tracking.** See Step 8 for a description of these techniques.
- **Acoustic Cameras**. See "Ecosystem Interactions Case Study Approach" for a description of the study design for this technique..

Protocols That Need Development/Testing

See Step 8 for a description of high definition aerial surveys, a protocol that needs further development/testing for sea turtles.

Selecting a Protocol for Effects Monitoring of Sea Turtles for the Humboldt Offshore Wind Power Project

The scale (pilot or commercial) and location of the project is expected to influence the selection of monitoring techniques. To assist with deciding on the appropriate method for a particular project's stressor and receptor, Table 7-7 identifies the advantages and disadvantages of these techniques. The feasibility of monitoring techniques in pilot vs. commercial projects, and at different types of sites, is also addressed. Because the different techniques provide different but limited types of information, multiple techniques may be selected in order to provide a thorough evaluation of potential effects on sea turtles.

Table 7-7 Advantages and Disadvantages of Techniques for Monitoring Effects of Offshore Wind Power on Sea Turtles.

Technique	Benefits	Limitations
Acoustic Cameras	• Can view interactions between sea turtles and underwater structures • Suitable method for pilot or commercial scale projects • Unlikely to cause behavioral disturbance • Provides depth-specific information on target distribution • Can be used in water with low visibility and without lighting	• Have a small detection range and therefore a low probability of detecting sea turtles, especially where they are rare • Does not provide population-level information on sea turtle distribution or abundance
Aerial surveys, Satellite tracking: see Table 7-6 for advantages and disadvantages of these techniques		

The selected protocol for evaluating sea turtle density and distribution for the Humboldt Offshore Wind Power Project would be aerial surveys (or high definition aerial surveys) continued from the previous years' baseline monitoring. This information would be used to compare pre- and post-installation sea turtle distribution in the project area and to inform whether the underwater structures or boats used in operations and maintenance are putting sea turtles at risk for collision or entanglement. It is expected that surveys will confirm that the project area is rarely used by sea turtles; if this is the case, then surveys could be discontinued after 1 or 2 years of post-installation monitoring (unless they are to be continued for seabirds and marine mammals). The protocol should be used in years of differing oceanographic conditions (e.g., El Niño, La Niña), as sea turtle distribution and abundance likely changes in response to interannual variability in ocean conditions along the California coast (Benson et al. 2007). If it is determined that sea turtles are using the project area more than expected (i.e., >10 sea turtles detected per year), a satellite tracking study could be conducted to evaluate the use of the project area and further assess risk to the species.

Acoustic cameras would not likely be utilized as a protocol to detect sea turtles for the Humboldt Offshore Wind Power Project due to the rarity of sea turtles in the project area, and the low probability of detecting them. Visual surveys using ROV may be conducted in order to survey fish and invertebrates at underwater structures. However, it is unlikely that a sea turtle could be detected using this technique because of their rarity in the project area although colonizing polyps, the sessile life stage of sea turtles primary prey, could be detected.

Vessel strike avoidance would likely be employed for marine mammals and sea turtles during all phases of the project, as it would likely be required by the National Marine Fisheries Service (NMFS 2008). While following the protocol, observers could occasionally collect useful information about the distribution of sea turtles in the project area.

8 CONCLUSIONS AND MAJOR FINDINGS

This project has resulted in three major conclusions. The first conclusion concerns the identification of priorities for monitoring potential environmental effects. Design and application of the *Protocols Framework* resulted in a priorities list for each type of renewable ocean energy technology (wave, tidal, and offshore wind) based on the interaction of stressors and receptors by scientific expertise, regulatory requirements, and stakeholder opinion. The study team believes, and the SMEs agree, that the priorities identified include the environmental interactions that are most likely to require baseline and/or effects monitoring for the siting and permitting of ocean energy projects. However, the specific list of priorities may change based on a specific technology and project location. Most importantly, as additional ocean energy projects are deployed and monitoring data are acquired, our ability to predict potential effects will increase. Similarly, regulatory changes such as listing or delisting of species, or changes in level of habitat protection, could also alter priorities.

The second major conclusion concerns the applicability of the *Protocols Framework*. The case studies demonstrate the utility of the framework for real and likely ocean energy projects and provide a proof of concept. The *Protocols Framework* can successfully screen many potential environmental interactions to identify those that require the application of baseline assessment and/or effects monitoring protocols. The broad applicability of the priorities for protocol development, the case studies, the team reviews of European protocols, and the SME reviews suggest that this framework should be portable across ocean renewable energy projects sited in the United States. However, the ability of the *Protocols Framework* to deliver specific applicable protocols or define information needs depends on the specificity of the information available about the technology and its stressor characteristics, as well as information on populations, communities, and habitats at the project site. This report is not intended, however, to proscribe baseline information and monitoring needs or specific protocols for any ocean renewable energy project.

The third major conclusion of this study concerns the portability of protocols across ocean energy technologies, while remaining sufficiently specific to be useful at a single site. The marine environment is highly variable in many scales across time and space. This may result in high variability in organism densities across days or months, or across mesoscale distances (i.e., kilometers to tens of kilometers), and also variability in the physical conditions that allow certain types of sampling technologies to be deployed. Such variability will also determine the sampling density required to demonstrate a given level of change. When choosing among existing protocols, or using a single existing protocol, a user must expect to adjust or adapt the protocol to the existing conditions at the chosen project site.

The case studies helped to pinpoint existing protocols applicable to ocean energy development, as well as point to those that require development. A summary of existing protocols appropriate for application across wave, tidal and offshore wind energy projects is found in Appendix E.

8.1 EXPECTED OUTCOMES

The final objective of this project is to define a process for the adoption of the *Protocols Framework* by ocean renewable energy stakeholders including regulatory agencies. However, even without the formal adoption of the *Protocols Framework* by federal and state agencies involved in project permitting, we see the following as the potential outcomes of the project.

Specifically, we expect use of the *Protocols Framework* to achieve:

1. A decrease in the amount of time and discussion spent in scoping permitting processes (such as NEPA) by allowing efficient identification and agreement on important environmental issues;
2. A decrease in the amount of time and resources expended by all stakeholders in considering monitoring needs;
3. A decrease the amount of time and resources expended by all stakeholders in agreeing on the necessary baseline and effects monitoring needed for siting a project;
4. The rapid identification and development of environmental monitoring protocols needed to support the renewable ocean energy industry; and
5. With the continued support of BOEM (and/or other federal agencies), a forum for the exchange of information developed by ocean energy projects, spring boarding off the *Protocols Framework* that will further normalize and standardize their application.

Please note: Nothing in this report is intended to prescribe baseline information and monitoring needs or protocols for any specific ocean renewable energy project. All project references and case studies in this report are hypothetical in nature. This analysis is designed to provide guidance to industry and regulatory agencies as it relates to project development, with the intent to directing limited resources to those issues most critical to commercial development.

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Appendix A

Supporting Materials for Case Studies

TABLE A-1. WAVE ENERGY: MOVING DEVICES/STATIC DEVICES AND CETACEANS.

Wave Energy Case Study #1 – Table Overview

Reedsport, Oregon

Stressor: *Moving Devices/Static Devices*

Receptor*: Cetaceans*

Stressor: Moving devices Receptor: Cetaceans Priority: Medium
Issue: Cetaceans could collide with moving components of wave energy converters while migrating through and/or feeding in the area.

Stressor: Static devices Receptor: Cetaceans Priority: High
Issue: Cetaceans could collide with static components (anchors, mooring lines) of installations while migrating through and/or feeding in the area.

Table A-1. Wave Energy: Moving Devices/Static Devices and Cetaceans.

Framework	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	Point absorber wave energy buoys in 62 to 69 m water depth in soft-sediment habitat approximately 2.5 miles from shore off south-central Oregon.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above

Table A-1. Wave Energy: Moving Devices/Static Devices and Cetaceans (continued).

3. Identify spatial and temporal scale of stressor	Three-dimensional footprint of stressor	Demonstration array footprint is 30 acres with 10 moving buoys, 16 subsurface floats (SSF), 16 concrete anchors, and up to 30 horizontal and 16 vertical mooring lines • Each buoy has a diameter of 37’ and a draft of 120’. • Subsurface floats will be 10 ‘ in diameter and 20 ‘ in height; the top of the SSF will be at 30’ depth • Anchors will be steel-reinforced concrete; 33’ x 33‘ by 26’ (high) expected to settle into the sediment and extend above the seabed 10‘. • Lines extending from the buoy to the SSF will range to a maximum depth of 30 to 50’; lines are synthetic polyester material, measuring four to five-inch in diameter
	Duration of stressor	Duration is constant, except for cessation of moving components during shutdown or maintenance, although all components will remain present.
4. Make preliminary assessment of exposure (spatial and temporal overlap) of receptor with stressor based on resource assessment	For EACH cetacean species that could occur in the project area, determine: • Population parameters (population status and trends, age structure) • Seasonal, diurnal, annual distribution • Migration paths (depth/distance from shore) • Migration characteristics (depth, speed, sinuosity, other relevant behaviors) • Feeding locations	Gray whales and harbor porpoises may occur commonly enough in the area to be measured. • Local population parameters for some species (gray, killer, harbor porpoises) are known • Distributions, migration timing and paths have been characterized in other areas of Oregon coast from at-sea (or aerial) and land surveys – timing and distribution in project areas may be estimated • Feeding locations are known in other areas of Oregon coast from at-sea (or aerial) and land surveys

	• Avoidance/ attraction behaviors	

Table A-1. Wave Energy: Moving Devices/Static Devices and Cetaceans (continued).

5. Identify Regulatory and Scientific thresholds	Scientific thresholds For species that could occur in project area: • Strikes with buoys or mooring lines causing or contributing to population declines; OR • Significant proportion of population being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities or increase in migration distances or movement to areas that may result in greater potential predation.)	Scientific thresholds Strikes with device components resulting in injury or death Changes in behavior, e.g., migration tracks or feeding locations
	Regulatory thresholds • ESA: Take or injury of one individual, harassment by presence of devices or traffic to devices • MMPA: Take of listed species through injury or mortality.	Regulatory thresholds • ESA-listed: Humpback, blue, fin, sei, sperm, and Southern Resident killer whale potentially present in project area but have not been observed. • MMPA Protected species: Gray, minke, and killer whales, harbor and Dall's porpoise, northern right whale dolphin, Pacific white-sided, Risso's dolphin and short-beaked common dolphin have been observed in the project area
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: • Diurnal, seasonal, annual distribution in project area • Feeding locations in project area

Table A-1. Wave Energy: Moving Devices/Static Devices and Cetaceans (continued).

7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Studies may include modeling collision and encounter rates based on baseline studies, continuing to monitor migration pathways and feeding behavior to detect avoidance/attraction behavior, monitor interactions
	Identify potential reference sites with similar physical/biological characteristics	Reference site may not be necessary but may be north or south of the installation site to make comparisons
8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols	See protocols for monitoring distribution and migration in Ortega-Ortiz & Mate (2008) and Ortega-Ortiz and Lagerquist (2009).
	Protocols that need development/testing	Cetacean census protocols for areas appropriate to wave energy installations.
9. Identify or develop effects monitoring protocols	Existing protocols	Effects monitoring protocols will be the same as baseline protocol for determining distributions, migration tracks, and feeding behavior.
	Protocols that need development/testing	SME’s may provide ideas for new protocols; see narrative text for more information.

TABLE A-2. WAVE ENERGY: STATIC DEVICES/ENERGY REMOVAL AND NEARFIELD HABITAT.

Wave Energy: High Priority Interaction #2 – Table Overview

Reedsport, Oregon

Stressor: *Static Devices/Energy Removal*

Receptor*: Nearfield Habitat (Sediment Characteristics)*

Stressor: Static Devices Receptor: Sediment Characteristics Priority: High
Issue: This interaction includes changes to the nearfield habitat, as changes to sediment characteristics are the major way by which the nearfield habitat will be changed. Anchors will change a small proportion of the benthic habitat from sedimentary to hard structure. The actual area of seafloor expected to be converted from soft-bottom to hard substrate by the deployment of concrete anchors for the Reedsport wave energy project with ten buoys is estimated at 0.12 km^2 (30 acres), about 1.7% of the buoy array footprint (Reedsport OPT Wave Energy Park 2010). A full project build-out with the same anchoring is expected to be similar to the 1.7% proportion. Scour around the anchoring systems will alter the distribution of sediment grain sizes in the vicinity.

Stressor: Energy Removal Receptor: Sediment Characteristics Priority: Medium
Issue: This interaction includes changes to the nearfield habitat, as changes to sediment characteristics are the major way by which the nearfield habitat will be changed. Removal of energy from the area by dynamic components of the devices may alter the distribution of sediment grain sizes in the vicinity.

Table A-2. Wave Energy: Static Devices and Nearfield Habitats.

Framework Steps	Information Needs	Case Study
1. Description of technology and site/location	User input for technology and site	Point absorber wave energy buoys in 62 to 69 m water depth in soft-sediment habitat approximately 2.5 miles from shore off south-central Oregon.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above

Table A-2. Wave Energy: Static Devices and Nearfield Habitats (continued).

3. Identify spatial and temporal scale of stressor	Three-dimensional footprint of stressor	Demonstration project area is $0.25 mi^2$ with an array of 10 moving buoys, 16 subsurface floats (SSF), 16 concrete anchors, and up to 30 horizontal and 16 vertical mooring lines. Anchors will be steel-reinforced concrete 33' x 33' x 26' (high) (10 m x 10 m x 8 m), expected to settle into the sediment and extend above the seabed 5.6' (1.7 m). The array footprint is expected to be approximately 30 acres.
	Duration of stressor	Duration of stressor due to static components is constant; cessation of energy extraction by moving components will occur during shutdown or maintenance.
4. Make preliminary assessment of exposure (spatial and temporal overlap) of receptor with stressor based on resource assessment	Spatial Overlap The extent of the effects of the stressor can be different depending on the number of devices deployed, the arrangement of devices, the distance from shore, and local factors.	Spatial Overlap The spatial extent of the effects will likely go beyond the spatial extent of the device array. Fine sediment scoured from around anchors may settle downstream and/or in the lee of the array. Modeling of wave and current dynamics as well as present sediment dynamic patterns in the area may provide opportunities for modeling effects of stressor.
	Temporal Overlap The effects of the stressor may vary seasonally.	Temporal Overlap The duration of these stressors on the sediment and thus, nearfield habitat, will be constant. However, the effects of the stressor may vary seasonally with variability in energy extraction and natural dynamics of the system.

Table A-2. Wave Energy: Static Devices and Nearfield Habitats (continued).

5. Identify Regulatory and Scientific thresholds	Potentially Applicable Regulations • The Clean Water Act stipulates if a project does something that brings about a change, which allows accumulation or different distribution of a pollutant; then that project may be held responsible. • Section 404 of the CWA regulates dredging and/or filling. • If the project results in changes to estuary dynamics (for example) that might affect an endangered species, then the Endangered Species Act could be applicable. • Oregon's Statewide Planning Goals & Guidelines Goal 17: Coastal Shorelands: OAR 660-015-0010(2) gives guidance that land use plans shall (1) inventory sedimentation sources and (2) minimize man-induced sedimentation. However, no regulations regarding changes to marine sediment characteristics exist.	Regulatory thresholds No regulatory thresholds for the physical characteristics of sediments are known to exist.
	Scientific thresholds	Scientific thresholds Changes in grain size classification. For example, shift from mud to sand or vice versa.
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	• Seasonal, annual sediment dynamics in project area • Wave heights/currents inshore/downstream of the future project area.

Table A-2. Wave Energy: Static Devices and Nearfield Habitats (continued).

7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	• Sediment grain size varying distances from the array • Wave heights/currents inshore/downstream of the future project area of the array after installation.
	Identify potential reference sites with similar physical characteristics	Shelf is narrow at the project location. Fine sand is present from the near shore to beyond project depth (60 m). The shelf widens north of the project location, so a reference site to the south is more appropriate.
8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols • Sediment collection and analysis • Sediment transport observations • Beach dynamics observations • Wave/current observations • Models	Selected Protocols Sediment collection and analysis Wave/current observations
	Protocols that need development/testing	New Protocols Applicable to Case Study Improved sediment transport observations and models Protocols for measuring factors for model input.
9. Identify or develop effects monitoring protocols	Existing protocols	Selected Protocols Effects monitoring protocols will be the same as baseline protocols
	Protocols that need development/testing	New Protocols Applicable to Case Study Improved sediment transport observations and models Protocols for measuring factors for model input.

TABLE A-3. WAVE ENERGY: STATIC DEVICES/ENERGY REMOVAL AND BENTHIC INVERTEBRATES.

Wave Energy Case Study #3 – Table Overview

Reedsport, Oregon

Stressor: *Static Devices/Energy Removal*

Receptor*: Benthic Invertebrates (as part of Ecosystem Interactions)*

Stressor: Static Devices Receptor: Benthic Invertebrates Priority: Medium
Issue: This interaction is likely due to changes to the nearfield habitat via changes to sediment characteristics. The actual area of seafloor expected to be converted from soft-bottom to hard substrate by the deployment of concrete anchors for the Reedsport wave energy project with ten buoys is estimated at 0.12 km^2 (30 acres), about 1.7% of the buoy array footprint (Reedsport OPT Wave Energy Park 2010). A full project build-out with the same anchoring is expected to be similar to the 1.7% proportion. Though this proportion is not likely representative of other WEC technologies or anchor types, the example serves to illustrate that the major ecological effect would not be the diminution of soft-bottom habitat and the fauna it supports, but rather the introduction of hard substrate, and new faunal associations thus supported. Scour around the anchoring systems will alter sediment characteristics in the vicinity.

Stressor: Energy Removal Receptor: Benthic Invertebrates Priority: Potential Effect
Issue: Removal of energy from the area by dynamic components of the devices may affect benthic invertebrates by altering sediment characteristics in the vicinity. Removal of energy from the system may also have a small effect on benthic invertebrate feeding and reproductive success.

Table A-3. Wave Energy: Static Devices/Energy Removal and Benthic Invertebrates.

Framework Steps	Generic Framework	Case Study
1. Description of technology and site/location	User input for technology and site	Point absorber wave energy buoys in 62 to 69 m water depth in soft-sediment habitat approximately 2.5 miles from shore off south-central Oregon.

Table A-3. Wave Energy: Static Devices/Energy Removal and Benthic Invertebrates (continued).

2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above
3. Identify spatial and temporal scale of stressor	Three-dimensional footprint of stressor	Demonstration array footprint is 0.25mi^2 with 10 moving buoys, 16 subsurface floats (SSF), 16 concrete anchors, and up to 30 horizontal and 16 vertical mooring lines Anchors will be steel-reinforced concrete; 33’ x 33‘ by 26’ (high) (6 m x 6 m x 3.1 m), expected to settle into the sediment and extend above the seabed 5.6‘ (1.7 m).
	Duration of stressor	Duration of stressor due to static components is constant; reduction energy extraction by moving components will occur during shutdown or maintenance.
4. Make preliminary assessment of exposure (spatial and temporal overlap) of receptor with stressor based on resource assessment	Spatial Overlap	Spatial Overlap The spatial extent of the effects will likely go beyond the spatial extent of the device array as the habitat may be altered beyond the footprint of the array.
	Temporal Overlap	Temporal Overlap The duration of these stressors on the sediment and thus, organisms living in that habitat, will be constant.

Table A-3. Wave Energy: Static Devices/Energy Removal and Benthic Invertebrates (continued).

5. Identify Regulatory and Scientific thresholds	Regulatory thresholds No regulatory thresholds for benthic invertebrates are known to exist.	Regulatory thresholds
	Scientific thresholds Change in organism density or species composition.	Scientific thresholds Epifaunal species of interest may include mysid and *Crangon* shrimp, as they are the bases of the trophic system in these nearshore habitats. Infaunal species of interest may include polychaete worms, as they are important benthic food sources and bioturbator, as well as olive snails (*Callianax* sp.) and *Axinopsida serricata*. Both have specific depth and grain size preferences, are important food sources, and *A. serricata* can be used as an indicator of organic enrichment conditions in sediments (Burd et al. 2008).
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Seasonal and annual population dynamics of infaunal and epi-benthic invertebrates in project area
7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Evaluation of potential changes to seasonal and annual population dynamics of benthic invertebrates associated with sedimentary habitats in project area Evaluation of potential changes to association of benthic invertebrates with sediment types Identification of invertebrates associated with hard substrate (devices and anchoring systems).
	Identify potential reference sites with similar physical/biological characteristics	Reference sites should include undisturbed sedimentary habitats and ‘natural’ hard substrate habitats.

Table A-3. Wave Energy: Static Devices/Energy Removal and Benthic Invertebrates (continued).

8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols	Existing protocols include coring protocols for surveying infaunal invertebrates and video/dive survey protocols for hard bottom observations.
	Protocols that need development/testing	No additional protocols need development
9. Identify or develop effects monitoring protocols	Existing protocols	Effects monitoring protocols may be the same as baseline protocols except for those areas within the perimeter of the project where some may be precluded, in which case additional protocols or approaches may be required.
	Protocols that need development/testing	Protocols that may need development are those to examine device components themselves for associated invertebrates.

TABLE A-4. WAVE ENERGY: ELECTROMAGNETIC FIELDS AND BENTHIC INVERTEBRATES, MIGRATORY FISHES, ELASMOBRANCHS AND SEA TURTLES.

Wave Energy Case Study #4 – Table Overview

Reedsport, Oregon

Stressor: *Electromagnetic Fields (EMF)*

Receptor: *Benthic Invertebrates, migratory fishes, elasmobranches and sea turtles*

Stressor: EMF   Receptor: Benthic invertebrates (crabs), migratory fishes, elasmobranchs, and sea turtles

Priority: Medium

Issue: Energy generating machines and power cables produce electromagnetic fields (EMF). While the electric field emanating from a device maybe rapidly damped in seawater in some circumstances, or propagated to significant distances if the local geology provides an electrically resistive waveguide within the seafloor, and power cables are commonly shielded to prevent leaking of electric fields, the magnetic field can propagate considerable distances and can induce an electric field in seawater. Furthermore, over the lifetime of operation of an installation, pin-hole leaks and physically compromised insulation could provide a potential pathway for electric current leakage from an otherwise shielded cable. Elasmobranchs use EMFs to locate prey and conspecifics; migratory fishes and sea turtles may use the earth’s magnetic fields for navigation. It has also been suggested that some benthic invertebrates, such as Dungeness crab, are sensitive to EMF; other species may have alterations to embryonic development from EMF exposure. Cables can be found in the water column from devices to the sea floor, and along the seabed, potentially buried, to bring power to shore.

Table A-4. Wave Energy: Electromagnetic Fields and Benthic Invertebrates, Migratory Fishes, Elasmobranchs, and Sea Turtles.

Framework	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	Point absorber wave energy buoys in 62 to 69 m water depth in soft-sediment habitat approximately 2.5 miles from shore off south-central Oregon.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above
3. Identify spatial and temporal scale of stressor	Three-dimensional footprint of deployed wave installation including configuration of EMF generators and transmission line geometry and topology, cable design, seafloor geologic structure including electrical resistivity structure	EMF signature, geometry and propagation to be determined… Map cable lines to determine areas of likely highest exposure. To understand the background geomagnetic geometry and electric field properties, map sub-seafloor electrical resistivity, carry out 3D modeling of EMF propagation relevant to bathymetry, underlying resistivity structure, and orientations and strength (electric and magnetic dipole moments) of generators and transmission lines.
	Duration of stressor – also need to take account of phase (i.e. operation or construction)	Duration is constant, except during shutdown or maintenance. There may be differences between AC and DC power cables.

Table A-4. Wave Energy: Electromagnetic Fields and Benthic Invertebrates, Migratory Fishes, Elasmobranchs, and Sea Turtles (continued).

4. Make preliminary assessment of exposure (spatial and temporal overlap) of receptor with stressor based on resource assessment	For EACH species of concern that could occur in the project area, determine: • Population parameters (population status and trends, age and size structure) • Seasonal, diurnal, annual distribution • Migration paths – diurnal and seasonal • Feeding locations/congregations • Known sensitivity to EMF • Avoidance/attraction behaviors including deviation Determine EMF output of device components and propagation of those EMFs in important habitats.	Crabs and some salmon species occur commonly enough in the area to be measured. • Local population parameters for some species may be known • Distributions, migration timing and paths may be known for some salmon but it may vary by life history stage • Feeding locations may be investigated EMF emissions, pattern/duration of emissions, geometry and field strengths of the PowerBuoy® system are TBD.
5. Identify Regulatory and Scientific thresholds	<u>Scientific thresholds</u> For species that could occur in project area: Significant proportion of population being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities or increase in migration distances and thus added energetic cost) Different life stages of species like salmonids may have different thresholds.	<u>Scientific thresholds</u> Significant changes in behavior, e.g., migration tracks or feeding locations Ecological thresholds that deal with metabolic requirements or energetic assessment. Embryonic development and juvenile growth changes.
	<u>Regulatory thresholds</u> ESA: Take or injury of individual, harassment by EMF MSFCMA: Regulates take of fisheries species	<u>Regulatory thresholds</u> ESA-listed: salmon, sturgeon, sea turtles MSFCMA: salmon, sturgeon, sharks

Table A-4. Wave Energy: Electromagnetic Fields and Benthic Invertebrates, Migratory Fishes, Elasmobranchs, and Sea Turtles.

6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: • Diurnal, seasonal, annual distribution in project area • Feeding locations in project area • EMF emissions, pattern/duration of emissions, and field strengths of the PowerBuoy® system. • The interactions between the PowerBuoy® system, transmission lines, end EMFs induced in that system by external geomagnetic/ionospheric (geomagnetic storm) activity
7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Studies may include continuing to monitor migration pathways and feeding behavior to detect avoidance/attraction behavior, monitor interactions
	Identify potential reference sites with similar physical/biological characteristics	Reference site may not be necessary but may be north or south of the installation site to make comparisons
8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols	Stock assessment protocols developed for other purposes may be applicable.
	Protocols that need development/testing	Protocols that need development are those to measure EMF of the PowerBuoy® system at biologically relevant levels and with relevant characteristics
9. Identify or develop effects monitoring protocols	Existing protocols	Effects monitoring protocols will be the same as baseline protocols for determining distributions, migration tracks, and feeding behavior.
	Protocols that need development/testing	Effects monitoring for harassment may need new protocol development.

TABLE A-5. WAVE ENERGY: NOISE/VIBRATION AND CETACEANS.

Wave Energy Case Study #5 – Table Overview

Reedsport, Oregon

Stressor: *Noise and Vibration*

Receptor*: Cetaceans*

Stressor: Noise/vibration Receptor: Cetaceans Priority: Medium

Issue: Cetaceans could be harassed by noise generated by wave energy converters while migrating through and/or feeding in the area.

Table A-5. Wave Energy: Noise/Vibration and Cetaceans.

Framework	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	Point absorber wave energy buoys in 62 to 69 m water depth in soft-sediment habitat approximately 2.5 miles from shore off south-central Oregon.
2. Identify Priority/Stressor Receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above
3. Identify spatial and temporal scale of stressor	Three-dimensional footprint of stressor	Acoustic signature and sound propagation from the device need to be determined. There will also be variations in magnitude of device-produced sound as a function of sea state.
	Duration of stressor	Duration is constant, except for cessation of noise of moving components during shutdown or maintenance, although noise due to strumming or mooring lines or other interactions of the ocean with static components will remain present.

Table A-5. Wave Energy: Noise/Vibration and Cetaceans (continued).

4. Make preliminary assessment of exposure (spatial and temporal overlap) of receptor with stressor based on resource assessment	For EACH cetacean species that could occur in the project area, determine: • Population parameters (population status and trends, age structure) • Seasonal, diurnal, annual distribution • Migration paths (depth/distance from shore) • Migration characteristics (depth, speed, sinuosity, other relevant behaviors) • Feeding locations • Avoidance/ attraction behaviors • Auditory range • Noise level and frequency of device components	Gray whales and harbor porpoises may occur commonly enough in the area to be measured. • Local population parameters for some species (gray, killer, harbor porpoises) are known • Distributions, migration timing and paths have been characterized in other areas of Oregon coast from at-sea (or aerial) and land surveys – timing and distribution in project areas may be estimated • Feeding locations are known in other areas of Oregon coast from at-sea (or aerial) and land surveys • Acoustic emissions of the PowerBuoy® system at the project location can be modeled.
5. Identify Regulatory and Scientific thresholds	<u>Scientific thresholds</u> For species that could occur in project area: Significant proportion of population being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities or increase in migration distances).	<u>Scientific thresholds</u> • Changes in behavior, e.g., migration tracks or feeding locations • Acoustic emissions of the PowerBuoy® system relative to background/ambient and to hearing for species of interest
	<u>Regulatory thresholds</u> ESA: Take or injury of one individual; harassment by presence of devices or traffic to devices, harassment by acoustics (Level A >180dB and Level B >120 dB for continuous noise and >=160dB for pulsed noise). MMPA: Harassment due to noise can be considered take if sufficient injury is inflicted (Level A) or a change in behavior is caused (Level B).	<u>Regulatory thresholds</u> ESA-listed: Humpback, blue, fin, sei, sperm, and Southern Resident killer whale potentially present in project area but have not been observed. MMPA Protected species: Gray, minke, and killer whales, harbor and Dall's porpoise, northern right whale dolphin, Pacific white-sided, Risso's dolphin and short-beaked common dolphin have been observed in the project area

Table A-5. Wave Energy: Noise/Vibration and Cetaceans (continued).

6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: • Diurnal, seasonal, annual distribution and abundance of species of concern in project area • Feeding locations in project area • Baseline, pre-deployment acoustic characterization of project site • Sound propagation modeling of project site based on physical characteristics.
7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Acoustic emissions of the system as a function of sea state Studies may include continuing to monitor migration pathways and feeding behavior to detect avoidance/attraction behavior, monitor interactions
	Identify potential reference sites with similar physical/biological characteristics	Reference site may not be necessary but may be north or south of the installation site to make comparisons
8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols	See protocols for monitoring distribution and migration in Ortega-Ortiz& Mate (2008) and Ortega-Ortiz and Lagerquist (2009) and for passive acoustic observations for cetaceans (Mellinger et al. 2007)
	Protocols that need development/testing	Protocols to census populations of marine mammals of concern. Protocols to measure acoustic emissions of the PowerBuoy® system will need to be refined.
9. Identify or develop effects monitoring protocols	Existing protocols	Effects monitoring protocols will be the same as baseline protocols for determining distributions, migration tracks, and feeding behavior.
	Protocols that need development/testing	Effects monitoring for acoustic harassment may need new protocol development.

TABLE A-6. WAVE ENERGY DATA, ANALYSES AND APPLICATIONS TABLE.

This table provides additional examples of the application of the protocols framework to wave energy projects, organized by priority stressor–receptor interaction (column 1). Protocols that exist for baseline assessment and effects monitoring are listed in column 2; for each interaction, the raw data needed and the preferred analyses of those data are listed in columns 3 and 4, respectively; the applicable spatial and ecological scales are in columns 5 and 6, respectively. Column 7 explains the applicability of the information to support siting and permitting of the project.

Table A-6. Wave Energy Data, Analyses and Applications Table.

1. Priority Stressor/Receptor Interaction	2. Protocols	3. Raw Data to be Collected	4. Analyses	5. Spatial Applicability	6. Ecological Scale	7. Application to Baseline Assessment and Post-Installation Monitoring
Static devices and sediment properties	**Baseline**: Mapping (multibeam sonar, acoustic backscatter) Seasonal sediment grabs	*Via mapping:* Depth, rugosity, grain size classification *Via sediment grabs:* Distribution of sediment grain sizes, total organic carbon, potentially other chemical characteristics across a site and over time	Determine how sediment characteristics are distributed across space and if they change across seasons.	Will only be applicable to the region where studies are conducted as the mapping is site specific and dynamics are dependent on local current patterns and local river inputs.	Changes in sediment properties may be localized or more widespread depending on the amount of energy extraction and local currents in the area.	Understanding 'natural' variability is necessary to evaluate potential project effects. Monitoring parameters are fewer than baseline because if there are not changes to the patterns of grain size distribution, then other parameters (e.g. TOC) are likely not changing. If changes are seen in grain size,

						additional sampling may be warranted to investigate what else is being affected.
	Effects monitoring: Seasonal sediment grabs	*Via sediment grabs:* Grain size distributions across a site and over time	Determine if grain sizes of sediment are different. Determine if scale or timing of sediment dynamics are different.			
Static devices and benthic invertebrates	**Baseline**: Sediment grabs to collect infaunal invertebrates Bottom trawls to collect epifaunal invertebrates Traps targeting specific mobile invertebrates These collections should ideally be made seasonally to determine	Numbers of each type of organism per grab/tow/ trap Area collected by grab, area covered by tow Grain size of sediment in grab	Calculate density of species of organisms collected (#/area of collection) Calculate CPUE of focus species Calculate diversity of collections Map communities of organisms across a site Determine	May be applicable to other regions with similar depth distribution and grain size as these factors are the primary ones in structuring benthic invertebrate communities.	Effects will most likely be at the community level as changes potentially could affect dynamics among species.	Determine distribution and abundances of species found in the area and baseline temporal trends. Understanding ‘natural’ variability is necessary to evaluate potential project effects.

	baseline temporal trends		relationships between particular species abundances or communities and habitat characteristics Determine baseline temporal and spatial variability in distributions or relationships			
	Effects monitoring: Same as baseline protocols Temporal intensity will be informed by data collected during baseline surveys	Same as baseline data	Same as baseline analyses plus determining if any of the distributions or relationships change, post-installation			
Generation of electromagnetic fields (not addressing potential	**Baseline**: Premonitoring estimation of existing minimum and	Field frequencies Field strengths Field directions Wave and current directions	Spatial and temporal analysis of the EM fields	Initially, will only be applicable to the specific project site due to	Limited to the area of the project and where biologically	Must await development of adequate protocols for the measurement of biological response

biological effects)	maximum EM fields. Conduct field sampling of EM fields with calibrated instruments.			spatial variability in baseline. With experience, however, comparisons of estimated to measured baseline fields may improve model estimates. Modeled estimates from cables, devices, junction boxes, etc., will also improve with experience.	meaningful EM fields are propagated from the project area; but also subject to biological characteristics of receptors, such as movement patterns and frequency of use of the subject area.	to EM fields by species (thresholds, sensitivities, and responses).
	Effects monitoring: Pre-monitoring, estimate source levels and propagation of EM fields produced by energy power generation equipment (cables, devices, junction boxes,	Same as baseline	Spatial and temporal analysis of EM fields after deployment of instrumentation in different wave and current conditions, and difference fields compared to baseline.			

	etc.) and likely spatial distribution and “hot spots” based on spatial layout at site. Measurement of EM fields at varying distances from potential sources using calibrated instrument with sensors fit to estimated signal strength.					

TABLE A-7. TIDAL ENERGY: MOVING DEVICES, CETACEANS AND PINNIPEDS.

Tidal Energy High Priority Interaction #1 – Table Overview

Admiralty Inlet – Puget Sound, Washington

***Stressor**: Moving Devices*

***Receptor:** Cetaceans and Pinnipeds*

Stressor: Moving Devices **Receptor: Cetaceans &Pinnipeds** **Priority: High**

Issue: Cetaceans and pinnipeds may potentially swim into rotating blades, by accident or out of curiosity.

Table A-7. Tidal Energy: Moving Devices, Cetaceans and Pinnipeds.

Framework Steps	Information Needs	Case study
1. Description of technology and site/location	Input technology and site specifics for the project site of interest.	20-40 ten-meter diameter open center OpenHydro turbines are planned for deployment in Admiralty Inlet, at depth of 50-60m. Each turbine foundation has a footprint of approximately 10 sq m. and will be placed directly on the seafloor. A power cable will run from each turbine to shore.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above
3. Identify spatial and temporal scale of stressor	Spatial Scale: Determine risk envelope within which marine mammals may be at risk from strike from turbine blades.	Spatial Scale: Identify and characterize nearfield habitat in Admiralty Inlet.
	Temporal Scale: Determine timing when turbine blades are rotating during tidal cycle, and operational behavior of turbines.	Temporal Scale: Determine temporal profile of turbine rotation in Admiralty Inlet, including cut in speed, tidal current speeds throughout annual tidal cycle, asymmetry of tidal currents in Admiralty Inlet.

Table A-7. Tidal Energy: Moving Devices, Cetaceans and Pinnipeds (continued).

4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment.	For EACH cetacean and pinniped population that are likely to occur in the project area, determine: • Population distribution, age structure, and reproductive rate. • Seasonal and diurnal patterns of movement through study area (portion of water body near turbines) • Behavior during diving, feeding, resting, and other common activities in study area. • Location and operational profile of tidal devices, including noise of the turbine, which may act as a deterrent to the animals, thus making them safer.	• Population and behavior information on Southern Resident killer whales (orca), harbor porpoises, harbor seals, as well as occasional visitors like grey whales, minke whales, pilot whales, Dahl's porpoise, and rare visitors like white-sided dolphins and humpback whales. • Operational profile of OpenHydro turbines in Admiralty Inlet, including hours that the blades will be spinning per tidal cycle, max RPM, and acoustic signature.
5. Identify Regulatory and Scientific thresholds	Scientific thresholds • For species that could occur in project area: Potential for interaction of marine mammals with turbines.	Scientific thresholds Loss of reproductive adults that could have an adverse impact on critically small populations, such as SRKW. Note: Steller sea lions are threatened throughout most of their home range, however they are doing well in the eastern DPS. This dichotomy may affect the regulatory requirements for addressing potential harm to this species.
	Regulatory thresholds **ESA**: taking of one or more individuals of a listed species through injury or mortality. **MMPA**: taking of listed species through injury or mortality.	Regulatory thresholds **ESA-listed species**: Take one or more Southern Resident killer whales (Orcinus orca) and Steller sea lions (*Eumetopiasjubatus*) **MMPA**: Injury or mortality to marine mammals

Table A-7. Tidal Energy: Moving Devices, Cetaceans and Pinnipeds (continued).

6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN.	Unknown information: • Detailed behavior information on dolphin species (SRKW, harbor porpoise) and on pinnipeds (harbor seals). • Operational profile of OpenHydro turbines.
7. Determine effects monitoring information needs	• Studies to evaluate effects of stressor on receptor.	• Behavioral model of marine mammals in Admiralty Inlet to determine risk of interaction with turbine blades while they are rotating.
	• Identify potential control reference sites with similar physical/biological characteristics and/or ensure good baseline monitoring of populations pre-installation.	• No reasonable control reference site available in Puget Sound or nearby with similar populations.
8. Identify or develop baseline monitoring protocols	• Existing protocols	• Population census and characteristics assessment (largely observational, a few satellite-tagged animals). However, population studies have not been performed consistently; repeating these studies will improve estimates.
	• Protocols that need development/testing	• Behavior modeling of marine mammals in Admiralty Inlet
9. Identify or develop effects monitoring protocols	• Existing protocols	• No established protocols, however some suggestions from Europe: • Video monitoring of OpenHydro devices at EMEC

Table A-7. Tidal Energy: Moving Devices, Cetaceans and Pinnipeds (continued).

	• Protocols that need development/testing	• Improved observational and tagging protocols for all marine mammal species in study area. • Acoustic (and maybe optical) observations of marine mammals interacting with turbine blades. • Stress gauges on blades that register collision with object over a specified weight (may not work on ducted turbine like OpenHydro; more useful for unducted turbines • Description/measurement of what a tidal turbine blade strike would look like on the various marine mammals (as opposed to other injuries). • May want to split monitoring protocols into: ▪ Monitoring of blades (acoustic or optical) for strike ▪ Monitoring of animals (tags, surface observations, acoustic) for attraction/avoidance.

TABLE A-8. TIDAL ENERGY: NOISE/VIBRATION AND CETACEANS.

Tidal Energy High Priority Interaction #2 - Table Overview

Admiralty Inlet - Puget Sound, WA

Stressor: *Noise and Vibration*

Receptor: *Cetaceans*

Stressor: Noise and Vibrations **Receptor: Cetacean** **Priority: High**

Issue: Acoustic output from rotating blades may disrupt cetacean communication and navigation.

Table A-8. Tidal Energy: Noise/Vibration and Cetaceans.

Framework Steps	Information Needs	Case study
1. Description of technology and site/location	Input technology and site specifics for the project sit of interest.	20-40 ten-meter diameter open center OpenHydro turbines are planned for deployment in Admiralty Inlet, at depth of 50-60m. Each turbine foundation has a footprint of approximately 10 sq m. and will be placed directly on the seafloor. A power cable will run from each turbine to shore.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above

Table A-8. Tidal Energy: Noise/Vibration and Cetaceans (continued).

3. Identify spatial and temporal scale of stressor	Spatial Scale: • Characterization of acoustic field produced by turbines (or other ocean energy structures)	Spatial Scale: • Acoustic field from Admiralty Inlet (under development by UW-NNMREC and PNNL).
	Temporal Scale: • Temporal changes in frequency, amplitude and duration of acoustic signals. • Changes in acoustic output of turbine over time (aging of mechanism), or with changing sea conditions.	Temporal Scale: • Records of changes in acoustic output over tidal cycles; sea conditions. • Changes in acoustic output over life of project.
4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment.	For EACH cetacean population that could occur in the project area, determine: • Population distribution, age structure, and reproductive rate. • Seasonal and diurnal patterns of movement through study area (portion of water body near turbines) • Behavior during diving, feeding, resting, and other common activities in study area. • Auditory range of each species. • Acoustic profile of turbine noise in study area over tidal cycles.	• Population and behavior information on Southern Resident killer whales, transient killer whales, harbor porpoises. Occasional visitors like gray whales, minke whales, Dall’s porpoise. • Acoustic profile of OpenHydro turbines. • Acoustic field in Admiralty Inlet, in relation to acoustic output of turbines.

Table A-8. Tidal Energy: Noise/Vibration and Cetaceans (continued).

5. Identify Regulatory and Scientific thresholds	Scientific thresholds For species that could occur in project area: • Acoustic output of turbines at or above threshold of cetaceans' hearing. • Behavioral changes of cetaceans in the vicinity of the turbines.	Scientific thresholds • Measurement of turbine noise in relation to audiograms of species' hearing. • Observations of changes in behavior of cetaceans in Admiralty Inlet, close to turbine field.
	Regulatory thresholds **ESA**: harassment of listed species by acoustics (Level A and Level B harassment) of 180dB and 120-160dB, respectively. **MMPA**: harassment due to noise can be considered a take if sufficient injury is inflicted.	Regulatory thresholds **ESA-listed species**: Southern Resident killer whales (*Orcinus orca*). • **MMPA protected species**: transient killer whales, harbor porpoise, and occasional sightings of gray whales, minke whales, Dall's porpoise.
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown information: • Detailed behavior information on key cetaceans (SRKW, harbor porpoise, Dall's). • Acoustic profile of turbines, acoustic field in Admiralty Inlet (data being acquired now).
7. Determine effects monitoring information needs	• Studies to evaluate effects of stressor on receptor. • Acoustic profile of turbine noise in study area over tidal cycles.	• Model of interaction of turbine noise field with auditory capabilities of cetaceans. • Behavioral response of cetaceans to turbine noise.
	• Identify potential reference sites with similar physical/biological characteristics.	• No suitable reference sites occur in Puget Sound or nearby estuaries

Table A-8. Tidal Energy: Noise/Vibration and Cetaceans (continued).

8. Identify or develop baseline monitoring protocols	- Existing protocols	- Population census and characteristics assessment (largely observational, few satellite-tagged animals).
	- Protocols that need development/testing	- Acoustic measurements of turbines and noise field.
9. Identify or develop effects monitoring protocols	- Existing protocols	- Behavioral response to stimuli (protocols exist for some species)
	- Protocols that need development/testing	- Improved observational and tagging protocols for all cetacean species in study area.

TABLE A-9. TIDAL ENERGY: ELECTROMAGNETIC FIELDS AND ELASMOBRANCHS.

Tidal Energy High Priority Interaction #3 - Table Overview

Admiralty Inlet - Puget Sound, WA

Stressor: *Electromagnetic Fields (EMF)*
Receptor*: Elasmobranchs*

Stressor: EMF **Receptor: Elasmobranchs** **Priority: High**

Issue: Changes to electromagnetic fields may affect elasmobranch behavior (i.e., that of sharks and rays), particularly foraging and feeding. Attraction, for example, can distract them away from hunting for prey.

Table A-9. Tidal Energy: Electromagnetic Fields and Elasmobranchs.

Framework Steps	Information Needs	Case study
1. Description of technology and site/location	Input technology and site specifics for the project sit of interest.	EMF output from rotating tidal turbine blades in Admiralty Inlet. EMF output potential from power cable along seafloor in Admiralty Inlet. 20-40 ten-meter diameter open center OpenHydro turbines are planned for deployment in Admiralty Inlet, at depth of 50-60m. Each turbine foundation has a footprint of approximately 10 sq m. and will be placed directly on the seafloor. A power cable will run from each turbine to shore.

Table A-9. Tidal Energy: Electromagnetic Fields and Elasmobranchs (continued).

2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above
3. Identify spatial and temporal scale of stressor	Spatial Scale: • Characterization of potential EMF field in vicinity of power cables, and rotating turbine blades (tidal only)	Spatial Scale: • Map power cable routes in Admiralty Inlet to develop the “worst case scenario” for areas of exposure of EMF to elasmobranchs. • Determine EMF profile from rotating tidal turbines in Admiralty Inlet.
	Temporal Scale: • Temporal regime of EMF emissions from turbines and power cables.	Temporal Scale:
4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment.	For EACH shark or ray population that occur in the project area, determine: • Population distribution, age structure, size, and reproductive rate. • Seasonal and diurnal patterns of movement, egg laying areas, and nursery grounds, in proximity to power cables and turbines. • Behavior that will bring the elasmobranchs in close quarters with power cables and/or turbines.	• Population and behavior information on six-gill sharks, basking sharks and dogfish. • Characterization of potential EMF field in vicinity of power cables and rotating turbine blades. • Ambient EMF fields in water body.

Table A-9. Tidal Energy: Electromagnetic Fields and Elasmobranchs (continued).

5. Identify Regulatory and Scientific thresholds	Scientific thresholds For species that could occur in project area: Significant changes in behavior of elasmobranchs in the vicinity of ocean energy devices that could affect the overall populations of animals, particularly in critically small populations.	Scientific thresholds Injury or significant changes in behavior of sharks in Admiralty Inlet that could affect the overall populations of animals, particularly in small populations such as the six-gill shark and basking shark. Dogfish populations in Puget Sound are not at risk.
	Regulatory thresholds **MSFCMA:** Sharks and rays are managed by NOAA Fisheries, who conduct stock assessments, monitor the species abundance of sharks, and implement fishery regulations that maximize the benefits of sharks as a resource for humans while also ensuring that we do not deplete shark populations. **IUCN Red List**: Many sharks and skates are listed as threatened or depleted, although no regulatory protection is afforded under the IUCN.	Regulatory thresholds **MSFCMA:** In Puget Sound, six (6) species of sharks and rays are managed by NOAA Fisheries under the groundfish fishery management plan; leopard shark, soupfin shark, spiny dogfish, big skate, California skate and long nose skate.
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown information: • Distribution and behavior information on shark species (six-gill sharks, basking sharks and dogfish) in Admiralty Inlet.

Table A-9. Tidal Energy: Electromagnetic Fields and Elasmobranchs (continued).

7. Determine effects monitoring information needs	• Studies to evaluate effects of stressor on receptor	• Characterization of potential EMF field in vicinity of power cables and rotating turbine blades. • Laboratory results that indicate sensitivity of shark species to various EMF components at levels resembling those of leaking power cables and tidal turbine rotors. • Observations of behavioral changes seen in sharks in vicinity of tidal turbines and power cables.
	• Identify potential reference sites with similar physical/biological characteristics	• Laboratory assessments of elasmobranch behavior in the vicinity of power cables and other EMF sources will inform field studies, in lieu of reference sites.
8. Identify or develop baseline monitoring protocols	• Existing protocols	• Stock assessment protocols developed for other locations are likely applicable (NOAA, state fisheries agencies), if they focus on the populations of concern.
	• Protocols that need development/testing	• Behavioral characteristics of shark species in Puget Sound.
9. Identify or develop effects monitoring protocols	• Existing protocols	• Kajiura has protocol but cannot be made public yet (proprietary to client) • Laboratory results that indicate sensitivity of shark species to various EMF components at levels resembling those of leaking power cables and tidal turbine rotors (PNNL and Kajiura) • Observations of behavioral changes seen in sharks in vicinity of tidal turbines and power cables (Andrew Gill)

	• Protocols that need development/testing	• Characterization of potential EMF field in vicinity of power cables and rotating turbine blades.

TABLE A-10. TIDAL ENERGY: MOVING DEVICES AND RESIDENT AND MIGRATORY FISH.

Tidal Energy High Priority Interaction #4 - Table Overview

Admiralty Inlet - Puget Sound, WA

Stressor: *Moving Devices*

Receptor*: Resident and Migratory Fish*

Stressor: Moving Devices   Receptor: Resident &Migratory Fish   Priority: Medium

Issue: Rotating turbine blades could present risk to resident fish, migratory strike, and/or sharks from strike (adults), entrainment or impingement (eggs, larvae, juveniles). High degree of uncertainty.

Table A-10. Tidal Energy: Moving Devices and Resident and Migratory Fish.

Framework Steps	Information Needs	Case study
1. Description of technology and site/location	Input technology and site specifics for the project site of interest.	20-40 ten-meter diameter open center OpenHydro turbines are planned for deployment in Admiralty Inlet, at depth of 50-60m. Each turbine foundation has a footprint of approximately 10 sq m. and will be placed directly on the seafloor. The vertical extent of the turbines is approximately15 meters off the seafloor. A power cable will run from each turbine to shore or to a junction box nearshore.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above

Table A-10. Tidal Energy: Moving Devices and Resident and Migratory Fish (continued).

3. Identify spatial and temporal scale of stressor	Spatial Scale: • Determine risk envelope within which adult fish may be at risk from strike from turbine blades. • Determine risk envelope for entrainment of juvenile fish and larvae to surface of turbine.	Spatial Scale: • Identify and characterize nearfield habitat in Admiralty Inlet. • Determine flow field in vicinity and through tidal turbines.
	Temporal Scale: • Determine risk when turbine is rotating, including day/night and state of the tide.	Temporal Scale: • Determine timeframe when turbine is rotating, including day/night profile, and state of the tide.
4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment.	For EACH fish population that occur in the project area, with emphasis on listed species, determine: • Population distribution, age structure, reproductive rate, and depth distribution. • Seasonal and diurnal patterns of movement through study area (portion of water body near turbines). • Understand behavior of adult and subadult fish in vicinity of turbines, including shoaling behavior for resident fish. • Understand temporal profile of turbine blades spinning during tidal cycle.	• Population structure and behavior information on Puget Sound Chinook and Hood Canal summer chum (including timing of fish runs), boccacio, yellow eye and canary rockfish, including depth of fish during each characteristic behavior. Yelloweye are most probable organisms at depths of turbines. • Operational profile for OpenHydro turbines in Admiralty Inlet, including hours that the blades will be spinning per tidal cycle, and max RPM.

Table A-10. Tidal Energy: Moving Devices and Resident and Migratory Fish (continued).

5. Identify Regulatory and Scientific thresholds	Scientific thresholds For species that could occur in project area: • Potential for interaction of adults and/or juveniles and larvae with turbines. • Ability to detect endangered fish (adults or juveniles) in the vicinity of the turbines.	Scientific thresholds • Loss of significant numbers of large reproductive females (for rockfish) and all reproductive adults for salmonids could have an adverse impact on critically small populations. • Loss of significant numbers of juveniles or larvae could have an adverse impact on critically small populations. • Detection of endangered fish in the area of the turbines.
	Regulatory thresholds **ESA**: taking of listed species through potential injury or mortality that could place population in jeopardy. **MSFCMA**: Degradation or removal of critical fish habitat in vicinity of turbines.	Regulatory thresholds **ESA-listed species**: Salmonids: Puget Sound Chinook and Hood Canal summer chum (threatened), boccacio (endangered), yellow eye and canary (threatened). **MSFCMA Critical Fish Habitat**: Nearshore waters in Admiralty Inlet are designated as critical habitat for salmon species and listed rockfish.
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown information: • Detailed stock assessments (including vertical and spatial distribution) of salmon runs and rockfish populations in Admiralty Inlet area, including collection of plankton for juvenile rockfish. • Assess rockfish habitat using ROVs in vicinity of project site as surrogate for rockfish presence. • Behavioral information on migratory and resident fish species.

Table A-10. Tidal Energy: Moving Devices and Resident and Migratory Fish (continued).

7. Determine effects monitoring information needs	• Studies to evaluate effects of stressor on receptor, including modeling the behavior around the turbine for each species of concern. • Develop measure of blade strike, perhaps stress gauges on turbine blades.	• Operational profile for OpenHydro turbines. Model of interaction of fish populations (adults and juveniles/larvae) with rotating turbine blades. • Behavioral response of resident and migratory fish to rotating turbine blades; these data will act as model validation.
	• Identify potential reference sites with similar physical/biological characteristics	• No reasonable reference site available in Puget Sound or nearby with similar populations.
8. Identify or develop baseline monitoring protocols	• Existing protocols	• Stock assessments for fish populations using standard survey methods, including trawling.
	• Protocols that need development/testing	• Stock assessment of resident and migratory fish populations using acoustics. • Assessment of presence, depths and biomass of juvenile fish and eggs in Admiralty Inlet.
9. Identify or develop effects monitoring protocols	• Existing protocols	• None
	• Protocols that need development/testing	• Depth distribution of fish populations. • Behavioral response of fish to turbine blades and wake field behind turbines; use of acoustics, as well as stereo cameras and ROVs, are preferred • Effect of entrainment of juveniles and larvae on surface of turbine.

TABLE A-11. TIDAL ENERGY: ENERGY REMOVAL AND SEDIMENT TRANSPORT AND WATER QUALITY.

Tidal Energy Medium Priority Interaction #5 - Table Overview

Admiralty Inlet - Puget Sound, WA

***Stressor**: Energy Removal*

***Receptor**: Sediment Transport and Water Quality*

Stressor: Energy Removal   Receptor: Sediment Transport & Water Quality   Priority: Medium

Issue: Changes in circulation due to energy removal could cause changes in water chemistry and farfield changes in sediment patterns in low energy areas and nearshore.

Stressor: Energy Removal   Receptor: Ecosystem InteractionsPriority: Medium

Issue: Removal of energy and change in flow in tidal basins could cause ”bottom-up” trophic impacts through changes in phytoplankton growth dynamics and the marine or estuarine food web.

These two stressor–receptor interactions will be treated together in the case study.

Water quality = CTD, dissolved oxygen, dissolved nutrients

Physical Parameters: Velocity, turbulence, temperature, and salinity

Table A-11. Tidal Energy: Energy Removal and Sediment Transport and Water Quality.

Framework Steps	Information Needs	Case study
1. Description of technology and site/location	Input technology and site specifics for the project sit of interest.	Basin-wide changes in Puget Sound in water quality and sediment transport. 20-40 ten-meter diameter open center OpenHydro turbines are planned for deployment in Admiralty Inlet, at depth of 50-60m. Each turbine foundation has a footprint of approximately 10 sq m. and will be placed directly on the seafloor. A power cable will run from each turbine to shore.
2. Identify Priority Stressor–receptor Interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives	Defined above
3. Identify spatial and temporal scale of stressor	Spatial Scale: • Circulation within the water body that could be affected by placement of tidal turbines, to include areas from seafloor to the nearshore and intertidal.	Spatial Scale: • Puget Sound basin south of Admiralty Inlet, with placement of turbines in Admiralty Inlet. • Also potential changes in Strait of Juan de Fuca (back effect – Garrett and Cummins paper) • Also, local scale changes of velocity profile in water column.
	Temporal Scale: • Whenever the turbine is turning, but persistent effect on flushing time of basin	Temporal Scale: • Whenever the turbine is turning, but persistent effect on flushing time of basin (ongoing)

Table A-11. Tidal Energy: Energy Removal and Sediment Transport and Water Quality (continued).

4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment.	Circulation and flushing time within the water body that could be affected by placement of tidal turbines, wave or offshore wind floats, and offshore wind monopoles, to include areas from the seafloor to the nearshore and intertidal. Basin-wide effects.	Understanding the circulation and flushing time in Puget Sound, as affected by the sill at Admiralty Inlet, will provide predictive power to determine likely outcome of deploying turbines.
5. Identify Regulatory and Scientific thresholds	<u>Scientific thresholds</u> - Degradation in farfield water quality/sediment transport that affects living organisms, particularly the base of the food chain, can reverberate throughout the food web, causing harm to populations of higher organisms.	<u>Scientific thresholds</u> - Reduced dissolved oxygen sufficient to affect fish and higher predators in Puget Sound. - Changes in stratification in Puget Sound
	<u>Regulatory thresholds</u> **CWA:** No degradation in water quality permitted; changes in water quality parameters (to include dissolved oxygen and nutrients, sediment load and transport, and toxic chemicals) must not exceed CWA limits. No degradation in beneficial uses of water body Zone of Dilution for nearfield??	<u>Regulatory thresholds</u> **CWA:** Changes in circulation farfield could contribute to reduced dissolved oxygen in some embayments in Puget Sound (i.e., Port Susan, Hood Canal).
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown information: - 3D hydrodynamic model needed to determine circulation, flushing time and sediment transport. - Detailed water quality and sediment transport from key points in the Puget Sound basin, as well as in the vicinity of the project area, for model calibration.

Table A-11. Tidal Energy: Energy Removal and Sediment Transport and Water Quality (continued).

7. Determine effects monitoring information needs	• Studies to evaluate effects of stressor on receptor	• Hydrodynamic model runs with simulated tidal turbines in place to determine changes in water circulation and flushing time that may affect farfield water quality and sediment transport. • Commercial scale may show up in farfield • Pilot scale may show changes in nearfield • Water quality, sediment patterns, and changes in farfield habitat data to validate model outcomes.
	• Identify potential reference sites with similar physical/biological characteristics	• No very good reference site (control) available in Puget Sound or nearby estuary. • Possibility for Tacoma Narrows as control/reference site for nearfield changes, more difficult for farfield
8. Identify or develop baseline monitoring protocols	• Existing protocols	• Numerical modeling methods (FVCOM). • Collection of water quality and sediment samples • Protocols that need development /testing transport methods available. • Collection of physical parameters, water quality and sediment transport samples for model validation.
	• Protocols that need development/testing	• Design and sensitivity of hydrodynamic model to determine water circulation.

Table A-11. Tidal Energy: Energy Removal and Sediment Transport and Water Quality (continued).

9. Identify or develop effects monitoring protocols	• Existing protocols	• Numerical modeling methods (FVCOM). • Collection of physical parameters, water quality and sediment transport variables.
	• Protocols that need development/testing	• Methods for model validation to increase accuracy of estimates of impact on circulation and flushing rates, including more detail close to turbine locations.

TABLE A-12. TIDAL ENERGY DATA, ANALYSES AND APPLICATIONS TABLE.

This table provides additional examples of the application of the protocols framework to tidal renewable ocean energy projects, organized by priority stressor–receptor interaction (column 1). Protocols that exist for baseline assessment and effects monitoring are listed in column 2; for each interaction, the raw data needed and the preferred analyses of those data are listed in columns 3 and 4, respectively; the applicable spatial and ecological scales are in columns 5 and 6, respectively. Column 7 explains the applicability of the information to support siting and permitting of the project.

Table A-12 Tidal Energy Data, Analyses and Applications Table.

1. Priority Stressor/Receptor Interaction	2. Protocols	3. Raw Data to be Collected	4. Analyses	5. Spatial Applicability	6. Ecological Scale	7. Application to Baseline Assessment and Post-Installation Monitoring
Energy Removal/Changes in Water Quality and Sediment Transport	**Baseline:**	Physical, chemical and biological parameters that describe water conditions, including temperature, salinity, dissolved oxygen, chlorophyll, sediment transport and other water quality parameters	Baseline and Effects Monitoring: Validation of computational model to ensure that hydrodynamics are realistic and accurate. Verification of changes in water quality and sediment transport parameters to ensure that	Modeling and verification data for baseline and effects monitoring applicable at scale of water body.	Changes in water quality may affect populations and communities of primary producers, and reverberate up food web to ecosystem level.	Validated computational model of water and sediment transport can establish baseline conditions in the tidal water body. Changes in water quality parameters and sediment transport can be used to indicate changes in water transport due to placement of tidal turbines, resulting in degradations or changes in water quality and/or

	:		changes in flow calculated by computational model results in accurate changes in parameters.			sediment transport.
	Effects Monitoring:	Similar parameters to determine change due to presence and operation of ocean energy devices				
Noise and Vibrations/ Cetaceans	**Baseline:**	Observation, tagging, and acoustic data on cetacean population and behavior Ambient acoustic profile of the marine environment	Behavioral model of cetaceans Model of acoustic profile for project area Model of acoustic profile for project area with the presence of tidal turbines	Local effect on cetaceans. Large project could affect cetaceans along migratory routes.	Effect at individual and population level of cetaceans.	Establish baseline cetacean populations and behavior

	Effects Monitoring:	Observation, tagging, and acoustic data on cetacean population and behavior Acoustic profile of project area with the presence of tidal turbines	Analyze for the changes in population and behavior of cetaceans			Changes in cetacean populations and behavior due to tidal turbines which can be used to inform mitigation and permitting for first and second generation projects.

TABLE A-13. OFFSHORE WIND ENERGY: MOVING DEVICES/STATIC DEVICES AND BIRDS.

Offshore Wind Energy High Priority Interaction #1

Humboldt County, California

Stressor: *Moving Devices and Static Devices*
Receptor: *Birds*

Stressor: Moving devices Priority: High
Issue: Birds could be struck by the wind turbines while flying through the area. Birds could also change their behaviors in response to wind turbines, either through avoidance of, or attraction to, turbines. Collision risk likely increases during high winds (birds tend to fly higher) and poor visibility.

Stressor: Static devices Priority: Medium
Issue: Birds could collide with wind turbine support towers above the surface of the water. Birds could also be attracted to support towers and structures for roosting. Collision risk increases during conditions when visibility is poor, e.g., foggy conditions.

Table A-13. Offshore Wind Energy: Moving Devices/Static Devices and Birds.

Framework steps	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	25, 5-MW Principal Power floating wind turbines, 8 km to 16 km offshore in open ocean
2. Identify priority stressor–receptor interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above
3. Identify spatial and temporal scale of stressor	Spatial scale	Rotor diameter 120-150 m; turbine hub height: 80-90 m; overall height: 140-165 m; Array footprint for 25 turbines is 24 km^2
	Temporal scale	Constant for license duration, except shutdown or maintenance

Table A-13. Offshore Wind Energy: Moving Devices/Static Devices and Birds (continued).

4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment	For each bird species that could occur in the project area, determine:	
	Proximity to breeding locations or colonies	Alcid nesting colony-Castle Rock NWR and offshore of Trinidad, CA; Marbled murrelet nesting in RNSP
	Seasonal, diel, annual distribution	• Xantus's murrelets only in fall primarily seaward of continental shelf break • Short-tailed albatross rare, primarily along continental shelf • Marbled murrelets generally ≤ 2 km from shore • Some limited/variable information for other species
	Feeding locations	Nearshore waters from Trinidad to Crescent City, CA a "hotspot" for multispecies aggregations of seabirds (likely feeding)
	Avoidance/ attraction behaviors	Alcids, storm-petrels, shearwaters, albatrosses attracted to lights; Gulls, cormorants, pelicans attracted to structures for roosting; some species may avoid turbines
	Flight pathways, timing (seasonal migration, daily feeding, weather conditions), and flight characteristics (height, speed, flocking or singular, other relevant behaviors)	Some general information on flight speed and direction related to wind conditions (Spear and Ainley 1997a, b). Nearshore of Reedsport, Oregon, majority (75-83%) of seabirds were reported flying <9 m above sea level (Geo-Marine, Inc., 2011)
5. Identify Regulatory and Scientific thresholds	<u>Regulatory thresholds</u> ESA-listed or State-listed species that could occur in project area: kill, harass, or injure one individual MBTA birds that could occur in the project area: could kill individuals	ESA-listed species that could be monitored for exceeding regulatory threshold: Marbled murrelet, short-tailed albatross State-listed species: None, project outside state waters MBTA birds: all

Table A-13. Offshore Wind Energy: Moving Devices/Static Devices and Birds (continued).

	Scientific thresholds For species that could occur in project area: • Strikes with turbines or support towers causing or contributing to population declines; OR • Significant proportion of population being directly killed or injured by strikes with turbines or support towers, or indirectly by altering behavior (avoidance or attraction to towers)	Types of species that could be monitored for exceeding scientific threshold: alcids, gulls, cormorants, pelicans, waterfowl, storm-petrels, shearwaters, albatrosses, shorebirds, jaegers, phalaropes
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: • Seasonal, diel, annual distribution • Feeding locations • Flight characteristics, pathways, and timing for most species
7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor:	Model collision and encounter rates, monitor flight pathways to detect avoidance/attraction behavior

Table A-13. Offshore Wind Energy: Moving Devices/Static Devices and Birds (continued).

8. Identify or develop baseline monitoring protocols	Existing protocols: Seasonal, annual distribution, feeding locations of bird species: • Boat surveys (Tasker et al. 1984, Briggs et al. 1987, Clarke et al. 2003, Spear et al. 2004) • Aerial surveys (Briggs et al. 1987, Camphuysen et al. 2004, Certain and Bretagnolle 2008) Identify foraging or activity areas, daily movements, and home range size of individual birds: • Satellite tracking (Perrow et al. 2006) • Radio- tracking (Burger and Shaffer 2008, Mellor and Maher 2008)	Selected protocols: • Aerial surveys to assess bird distribution and abundance in project area • Boat surveys to validate aerial survey data and to assess flight height, direction, and behavior of birds
	Protocols that need development/testing: • High definition aerial surveys (Thaxter and Burton 2009, protocols being developed by BOEM) • Doppler weather surveillance radar (Ruth et al. 2008)	
9. Identify or develop effects monitoring protocols	Existing protocols: Compare pre- and post-installation bird distribution: • Boat surveys and/or aerial surveys to	Selected protocols: • Radar in conjunction with thermal imagery mounted on wind turbine platforms • Aerial surveys and boat surveys to validate radar/thermal

	determine if birds are attracted to or avoiding turbines Identify key foraging or activity areas, daily movements, and home range size of individual birds: • Satellite tracking or radio-tracking • Compare pre- and post-installation flight pathways and timing, flight characteristics, detect avoidance/attraction behavior, model collision and encounter rates for bird species: • Radar mounted on a boat, onshore, or platform to detect altitude and trajectories of birds (Desholm et al. 2004, Geo-Marine, Inc. 2004) • Radar/thermal imagery to identify size/species, flight direction (Hüppop et al. 2006, Gauthreaux and Livingston 2006)	imagery data and compare pre- and post-installation bird distribution
	Protocols that need development/testing: • Acoustic monitoring to determine use of project area by vocalizing bird species (protocol being developed by BOEM) • Integrated sensor array to continuously monitor interactions (including impacts) of birds and bats on blades,	

	nacelles and towers of wind turbines (being developed by NNMREC with funding from DOE)	

TABLE A-14. OFFSHORE WIND ENERGY: STATIC DEVICES AND ECOSYSTEM INTERACTIONS, NEKTONIC INVERTEBRATES, RESIDENT FISHES, MIGRATORY FISHES, AND ELASMOBRANCHS.

Offshore Wind Energy High Priority Interaction #2

Humboldt County, California

Stressor: *Static Devices*

Receptor: *Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, Elasmobranchs*

Stressor: Static devices   Receptor: Ecosystem interactions   Priority: High

Issue: Underwater hard structures may serve as fish attractors (FAD effect or reef effect), attracting a different assemblage than would have been found over soft bottom habitat.

Stressor: Static devices   Receptor: Nektonic inverts, Resident fishes, Migratory fishes, Elasmobranchs Priority: Medium

Issue: The addition of hard substrate may result in attraction of these receptors to the project area (FAD effect or reef effect).

Table A-14. Offshore Wind Energy: Static Devices and Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, and Elasmobranchs.

Framework Steps	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	Soft-bottom habitat, 8 km to 16 km offshore at depths of 70-180 m
2. Identify priority stressor–receptor interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above
3. Identify spatial and temporal scale of stressor	Spatial scale	Array footprint is 24 km^2 for 25 turbines; each turbine mounted on a floating platform moored with 4-6 mooring lines attached to drag embedded anchors; hull (platform) draft approximately <20 m

	Temporal scale	Constant for license duration

Table A-14. Offshore Wind Energy: Static Devices and Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, and Elasmobranchs (continued).

4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment	For fish and invertebrate indicator species or assemblages that could occur in the project area, determine:	
	Habitat types/associations	• Species associated with soft-bottom habitat (benthic and epibenthic invertebrates, rays, flatfishes, groundfish) • Species associated with the water column (pelagic fish, migratory fish)
	Diel, seasonal, interannual distribution patterns	• Migratory fish (salmon, green sturgeon, albacore tuna), some species more ephemeral/unpredictable (squid, sharks, pelagic fish), some species year-round (groundfish)
5. Identify Regulatory and Scientific thresholds	Regulatory thresholds • ESA-listed or State-listed species that could occur in project area: kill, harass, or injure one individual • Essential Fish Habitat (EFH) (including Habitat Areas of Particular Concern) that could be adversely affected by the project (e.g., adverse effects are impacts from the project that decrease the quality and/or quantity of EFH, see 67FR2343)	Listed species that could be monitored for exceeding regulatory threshold: • ESA-listed: Chinook salmon, coho salmon, steelhead, green sturgeon, eulachon • State-listed: None, project outside of state waters • EFH for many fish species, notably rockfishes and other groundfish, highly migratory fishes, coastal pelagic species
	Scientific thresholds For fish and invertebrate	Species groups that could be monitored for exceeding scientific threshold: • Resident fishes (rockfish, flatfish)

	species that could occur in project area: underwater hard structures attract different fish and invertebrate species than pre-project conditions, modifying species assemblages or food webs	• Migratory fish (salmon, sturgeon) • Elasmobranchs (sharks, skates, rays) that could be attracted to hard structure • Algae or invertebrates colonizing hard structure including jellyfish polyps

6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	• Unknown baseline information: diel, seasonal, interannual distribution patterns of many fish and invertebrate species • Some information on species assemblages and potentially seasonal distributions may be known based on commercial and recreational fisheries, and information from surveys conducted in similar habitats and depths at different locations
7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Fish and invertebrate species assemblage and distribution changes associated with hard structure on bottom and in water column: • Reef effect: Species are attracted to the underwater structures resulting in species composition changes • FAD effect: Pelagic fish species are attracted to near-surface structures resulting in species composition changes • Listed fish species may be more vulnerable to predation due to attraction of listed fish and their predators to structures • Structure and changes to fish assemblage could affect demersal fish and invertebrate assemblage

Table A-14. Offshore Wind Energy: Static Devices and Ecosystem Interactions, Nektonic Invertebrates, Resident Fishes, Migratory Fishes, and Elasmobranchs (continued).

8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols: Diel, seasonal, interannual and spatial distribution of soft-bottom fish and epibenthic invertebrates: • Trapping (Terrill et al. 2009) • Epibenthic trawling (Davies et al. 2001, Curtis and Coggen 2007, Terrill et al. 2009, Lindeboom et al. 2011, Trippel 2011) • Visual surveys (diver/diver operated video, towed video, ROV)(Somerton and Glendhill 2005, Coggen et al. 2007, Pacunski et al. 2008, Yoklavich and O'Connell 2008, Love et al. 2009, Martin and Lowe 2010) Diel, seasonal, interannual and spatial distribution of pelagic fish and invertebrate communities and biomass of pelagic fish: • Mobile or stationary hydroacoustic surveys (Taylor and Maxwell 2007, Georgakarakos and Kitsiou 2008, Parker-Stetter et al. 2009, Trenkel et al. 2008, Lindeboom et al. 2011) • Ground-truth with mid-water trawl (Lindeboom et al. 201coggen 20071, Arimitsu et al. 2003), multi-mesh gill net (Boldt and Haldorson 2002, Duffy and Beauchamp 2008), or hook and line sampling (Starr et al. 2010) Diel, seasonal, interannual and spatial distribution patterns of migratory listed fish:	Selected protocols: • Towed video/ROV transects to evaluate demersal fish, epibenthic invertebrates • Acoustic telemetry receivers to detect presence of tagged fish in the project area • Demersal fish and epibenthic invertebrates using trawls (beam trawl or other "quantitative" trawl) and traps • Mobile hydroacoustic monitoring for pelagic "targets", evaluating diel and seasonal distribution patterns at the project site, ground truth with multi-mesh gill nets

	• Telemetry (Erickson and Hightower 2007, Lindley et al. 2008, Block et al. 2010, Payne et al. 2010)	

<table>
<tr>
<td rowspan="2">9. Identify or develop effects monitoring protocols</td>
<td colspan="2">Protocols that need development/testing:
• Visual and acoustic cameras (Somerton and Glendhill 2005, Shortis et al. 2007)
• Acoustic-optical systems (Ryan et al. 2009)
• Mobile and stationary acoustics (protocol being developed by Horn et al. funded by BOEM)
• Passive acoustic monitoring for sound-producing species (Širović et al. 2009)
Autonomous underwater vehicles for acoustic, oceanographic, visual, and telemetry monitoring) (Fernandes et al. 2003)</td>
</tr>
<tr>
<td><u>Existing protocols:</u>
Reef effect:
1.Fish communities evaluated with hydroacoustics (Wilson et al. 2003, Doray et al. 2008) to determine if biomass associated with hard structure on the bottom (note will likely take some time for species to recruit to new habitat)
2. If/when biomass observed, ground-truth species composition using visual surveys (camera/video surveys with ROV, SCUBA, submersible); resident fish and epibenthic invertebrate species composition, size and relative abundance using hook and line</td>
<td><u>Selected protocols:</u>
• Reef effect monitoring: mobile split-beam echosounder verified once targets are consistently found with ROV if visibility is sufficient, otherwise hook and line sampling
• Pelagic fishes monitoring: mobile downward and sideways looking hydroacoustics until stationary upward looking methods are developed or until consistent targets are observed. Ground truth with ROV or diver observation (if visibility is sufficient), otherwise with multi-mesh gill net
• BACI design for demersal fish and epibenthic invertebrates, using trawls (beam trawl or other “quantitative” trawl) and traps</td>
</tr>
</table>

	(Starr et al. 2010), visual surveys (see baseline on visual surveys, also Dempster 2004, Wilhelmsson et al. 2006), trapping (Terrill et al. 2009), baited video (Shortis et al. 2007) FAD effect: • Resident fishes, migratory fishes, nektonic invertebrates, and elasmobranchs use hydroacoustics (stationary or mobile) (Wilson et al. 2003, Doray et al. 2008) or acoustic cameras to determine if biomass is associated with hard structure in the water column/on the surface • If biomass is observed, ground-truth species composition using visual surveys (camera/video, ROV, SCUBA, submersible) • Species composition, size and relative abundance using multi-mesh gillnets, mid-water trawl (if possible given mooring lines) • Telemetry for behavior, residency time of migratory species such as green sturgeon, adult salmon, sharks (Winters et al. 2010) Changes to diel, seasonal, interannual and spatial distribution patterns of soft-bottom fish and epibenthic invertebrates: • Trapping (Terrill et al. 2009) • Epibenthic trawling (Davies et al. 2001, Curtis and Coggan 2007, Terrill et al. 2009, Lindeboom et al. 2011, Trippel 2011) • Visual surveys (diver/diver operated	• Use acoustic telemetry to evaluate presence in the project area of tagged species (e.g., green sturgeon, sharks) • Species captured by hook and line or multi-mesh gillnet for evaluation of food habits

	video, towed video, ROV) (Somerton and Glendhill 2005, Yoklavich and O'Connell 2008, Pacunski et al. 2008, Love et al. 2009, Martin and Lowe 2010) Predation: • Gut content analysis of predatory fish to determine diet and predation on listed fish species (Boldt and Haldorson 2002, Nairn et al. 2004, Duffy and Beauchamp 2008, Jaquemet et al. 2011)	
	Protocols that need development/testing: • Visual and acoustic cameras (Somerton and Glendhill 2005, Shortiset al. 2007) • Acoustic-optical systems (Ryan et al. 2009) • Mobile and stationary acoustics (protocol being developed by Horn et al. funded by BOEM) • Passive acoustic monitoring for sound-producing species (Širović et al. 2009) Autonomous underwater vehicles for acoustic, oceanographic, visual, and telemetry monitoring) (Fernandes et al. 2003)	

TABLE A-15. OFFSHORE WIND ENERGY: MOVING DEVICES AND BATS.

Offshore Wind Energy High Priority Interaction #3

Humboldt County, California

***Stressor**: Moving Devices*

***Receptor**: Bats*

Stressor: Moving devices Receptor: Bats Priority: High

Issue: Bats could collide with wind turbines while flying through the area, or be injured or killed from barotrauma. Bats could also change their behaviors in response to wind turbines, by attraction to the turbines (increasing risk of collision).

Table A-15. Offshore Wind Energy: Moving Devices and Bats.

Framework steps	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	25, 5-MW Principal Power floating wind turbines, 8 km to 16 km offshore in open ocean
2. Identify priority stressor–receptor interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above
3. Identify spatial and temporal scale of stressor	Spatial scale	Rotor diameter 120-150 m; turbine hub height: 80-90 m; overall height: 140-165 m; Array footprint is 24 km^2
	Temporal scale	Constant for license duration, except shutdown or maintenance

Table A-15. Offshore Wind Energy: Moving Devices and Bats (continued).

4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment	For bat species that could occur in the project area, determine:	
	Proximity of breeding locations	Coastal forests (i.e., Redwood National and State Parks)
	Seasonal distribution	Most likely to occur offshore during migration in fall (Cryan and Brown 2007)
	Attraction behaviors	Could be attracted to offshore structures for roosting
	Flight pathways, timing, characteristics (height, speed, etc.)	Fly lower early evening and early morning when transitioning between roost and migration, more common following overcast nights, low wind, low barometric pressure (Cryan and Brown 2007); forage under 125 m; may migrate at very low altitudes at sea (<10 m; Ahlen et al. 2009)
5. Identify Regulatory and Scientific thresholds	Regulatory thresholds ESA-listed or State-listed species that could occur in project area: kill, harass, or injure one individual	ESA-listed species that could be monitored for exceeding regulatory threshold: none State-listed species: none
	Scientific thresholds For species that could occur in project area: • Strikes with turbines causing/contributing to population declines; OR • Significant proportion of population being directly killed or injured by strikes with turbines, or indirectly by altering behavior (attraction to towers or lighting)	Bat species that could be monitored for exceeding scientific threshold: hoary bat, silver-haired bat, western red bats
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: • Flight pathways, timing, and characteristics in project area

Table A-15. Offshore Wind Energy: Moving Devices and Bats (continued).

7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Model collision and encounter rates
8. Identify or develop baseline monitoring protocols to address information needs	Existing protocols: • Acoustic monitoring to detect bats in project area (Kunz et al. 2007) • Night-vision observations with night-vision goggles, scopes, infrared or thermal cameras to view flight behavior (Gauthreaux and Livingston 2006, Kunz et al. 2007, Rodrigues et al. 2008) • Marine radar to assess flight characteristics (Kunz et al. 2007)	Selected protocols: • Acoustic monitoring from a boat during fall migration • Night-vision observations from a boat during fall migration
	Protocols that need development/testing: • Acoustic monitoring protocol for offshore wind being developed by BOEM • Radar for birds and bats for offshore wind projects	
9. Identify or develop effects monitoring protocols	Existing protocols: • Acoustic monitoring to detect bats in project area (Kunz et al. 2007) • Night-vision observations with night-vision goggles, scopes, infrared or thermal cameras to view flight behavior (Gauthreaux and Livingston 2006, Kunz et al. 2007, Rodrigues et al. 2008) • Marine radar to assess flight characteristics (Kunz et al. 2007)	Selected protocol: • Acoustic monitoring from automated devices installed on wind turbines • Night-vision observations from a boat during fall migration • Radar, if being conducted to also monitor seabirds

Table A-15. Offshore Wind Energy: Moving Devices and Bats (continued).

	Protocols that need development/testing: • Acoustic monitoring protocol for offshore wind being developed by BOEM • Radar for birds and bats for offshore wind projects • Integrated sensor array to continuously monitor interactions (including impacts) of birds and bats on blades, nacelles and towers of wind turbines (being developed by NNMREC with funding from DOE)	

TABLE A-16. OFFSHORE WIND ENERGY: STATIC DEVICES/BOATS AND SEA TURTLES.

Offshore Wind Energy High Priority Interaction #4

Humboldt County, California

Stressor: *Static Devices and Boats*

Receptor: *Sea Turtles*

Stressor: Static devices Priority: Medium

Issue: Sea turtles could collide with structures and become entangled in mooring lines. Lost fishing gear in the marine environment could become entangled in the mooring lines, further increasing the likelihood that sea turtles will become entangled.

Stressor: Boat traffic Priority: Medium

Issue: Boats used during construction and maintenance of wind turbines could collide with sea turtles.

Table A-16. Offshore Wind Energy: Static Devices/Boats and Sea Turtles.

Framework steps	Information needs	Case study
1. Description of technology and site/location	User input for technology and site	Soft-bottom habitat, 8 km to 16 km offshore at depths of 70-180 m
2. Identify priority stressor–receptor interactions	User evaluation of expert opinion, regulatory and stakeholder perspectives.	Defined above

Table A-16. Offshore Wind Energy: Static Devices/Boats and Sea Turtles.

3. Identify spatial and temporal scale of stressor	Spatial scale	Array footprint is 24 km^{2,} for 25 turbines; each turbine mounted on a floating platform moored with 4-6 mooring lines attached to anchors (need size) Total amount of hard structure on the bottom = XXXX-YYYY ha, total amount of platform structure subsurface (in volume and area)
	Temporal scale	Constant for license duration
4. Identify known spatial and temporal overlap of receptor with stressor, based on resource assessment	For sea turtle species that could occur in the project area, determine:	
	Proximity of breeding locations	Nowhere near the project area
	Seasonal, annual distribution	Leatherback turtle: pelagic, extremely rare in project area but most likely in summer/fall and during El Niño years when waters are warmer, and where prey (sea nettles) are found
	Avoidance/ attraction behaviors to underwater structure or boats	Leatherback turtles not known to be attracted to underwater static devices or boats
5. Identify Regulatory and Scientific thresholds	<u>Regulatory thresholds</u>: ESA-listed or State-listed species that could occur in project area: kill, harass, or injure one individual or adversely modify critical habitat	ESA-listed species that could be monitored for exceeding regulatory threshold: leatherback turtle State-listed species: none No critical habitat in project area
	<u>Scientific thresholds</u>: For sea turtle species that could occur in project area, collision or entanglement with underwater components causing or contributing to population declines	Species that could be monitored for exceeding scientific threshold: leatherback turtle
6. Determine baseline monitoring information needs	Information from #4 that is UNKNOWN	Unknown baseline information: seasonal and annual distribution of leatherback turtle

Table A-16. Offshore Wind Energy: Static Devices/Boats and Sea Turtles.

7. Determine effects monitoring information needs	Studies to evaluate effects of stressor on receptor	Determine if sea turtles are attracted to and/or becoming entangled or colliding with underwater components, or with boats used in installation and maintenance of turbines
8. Identify or develop baseline monitoring protocols	Existing protocols: • Aerial surveys to evaluate seasonal, annual distribution of sea turtles (Benson et al. 2007) • Satellite tracking to determine individual movement and use of project area (Koyayashi et al. 2008, Benson et al. 2011)	Selected protocol: Aerial surveys to evaluate seasonal, annual distribution of leatherback turtles
	Protocols that need development/testing: High definition aerial surveys (Thaxter and Burton 2009, protocols being developed by BOEM) to assess sea turtle distribution/ density	
9. Identify or develop effects monitoring protocols	Existing protocols: • Aerial surveys to evaluate seasonal, annual distribution of sea turtles (Benson et al. 2007) • Satellite tracking to determine individual movement and use of project area (Koyayashi et al. 2008, Benson et al. 2011) • Acoustic cameras to view interactions between sea turtles and underwater structures	Selected protocol: Aerial surveys to evaluate seasonal, annual distribution of leatherback turtles
	Protocols that need development/testing: High definition aerial surveys (Thaxter and Burton 2009, protocols being developed by BOEM) to assess sea turtle distribution/ density	

TABLE A-17. OFFSHORE WIND ENERGY DATA, ANALYSES, AND APPLICATIONS TABLE.

This table provides additional examples of the application of the protocols framework to offshore wind renewable ocean energy projects, organized by priority stressor–receptor interaction (column 2). Protocols that exist for baseline assessment and effects monitoring are listed in column 2; for each interaction, the raw data needed and the preferred analyses of those data are listed in columns 3 and 4, respectively; the applicable spatial and ecological scales are in columns 5 and 6, respectively. Column 7 explains the applicability of the information to support siting and permitting of the project.

Table A-17. Offshore Wind Energy Data, Analyses, and Applications Table.

1. Priority Stressor/Receptor Interaction	**2.Protocols**	**3.Raw Data to be Collected**	**4.Analyses**	**5.Spatial Applicability**	**6.Ecological Scale**	**7.Application to Baseline Assessment and Post-Installation Monitoring**
Moving Devices and Static Devices/ Birds	**Baseline:**	Species and abundance of birds in transects in the project area using aerial or boat surveys	Estimate density and abundance of birds; correlate distribution with oceanographic variables	Local effect on bird distribution in project area and adjacent areas	Effect at individual and population level of birds	Establish baseline bird distribution and abundance
	Effects Monitoring:	Flight patterns of targets (birds) using radar and thermal imagery. Species and abundance of birds in transects in the	Determine seasonal variability of flight characteristics and migratory patterns. Model collision risk of birds with turbines			Risk of bird collisions with turbines, changes in bird distribution around turbines and structures. Can be used to inform mitigation and permitting

		project area using aerial or boat surveys				
Static Devices/ Ecosystem Interactions, Nektonic Invertebrates, Resident and Migratory Fishes, Elasmobranchs	**Baseline:**	Diel, seasonal and interannual distribution, and habitat associations of fish and invertebrates; potential survey techniques include trapping, trawling, purse seine, gill nets, hook and line, hydroacoustic surveys, visual surveys, acoustic telemetry	Estimate fish and invertebrate distribution, stratified by depth, bottom habitat, season, diel patterns	Local effect on fish and invertebrate distribution in project area associated with underwater structures	Effect on population level of fish and invertebrates, species assemblages	Establish baseline fish and invertebrate diel, seasonal and interannual distribution, and habitat associations
	Effects Monitoring:	Species assemblages and densities associated with underwater structures; potential survey techniques	BACI or ACI design to evaluate species assemblages and densities pre and post-installation			Determine if underwater structures are acting as a FAD or reef, changing distribution and abundance of soft-bottom fish and

		include trapping, trawling, purse seine, gill nets, hook and line, hydroacoustic surveys, visual surveys, acoustic telemetry				epibenthic invertebrates, or increasing predation on listed fish species. Can be used to inform mitigation and permitting.
Moving Devices/Bats	**Baseline:**	Bat presence, activity, abundance, flight behavior, direction, and altitude using acoustic monitoring, night-vision observations, marine radar	Summary statistics of presence, activity, relative abundance, flight behavior, direction, and altitude of bats detected; correlate with weather conditions and season	Local effect on presence of bats in project area	Effect at individual and population level of bats	Establish baseline use of project area by bats
	Effects Monitoring:	Bat presence, activity, relative abundance, flight behavior, direction, altitude, response to	Summary statistics of presence, activity, relative abundance, flight behavior, direction, and altitude of bats			Determine if bats are potentially attracted to wind turbines, or using the project area as a migration route or stopover. Can be used to inform

		turbines	detected; correlate with weather conditions and season			mitigation and permitting.
Static Devices and Boat Traffic/ Sea Turtles	**Baseline:**	Sea turtle abundance using aerial surveys. Movement of individuals using satellite tracking.	Estimate density and abundance of sea turtles in project area. Key foraging locations and daily movements of individual sea turtles.	Local effect on presence of sea turtles in project area	Effect at individual and population level of sea turtles	Establish baseline use of project area by sea turtles
	Effects Monitoring:	Sea turtle abundance using aerial surveys. Movement of individuals using satellite tracking.	Estimate density and abundance of sea turtles in project area. Key foraging locations and daily movements of individual sea turtles.			Determine if sea turtles may be attracted to underwater structures, at risk of collisions with boats, or using the project area. Can be used to inform mitigation and permitting.

Appendix B

Supporting Materials for Priority Interactions

Wave Energy Table 1: Expert Opinion

Table B-1. Potential importance of generic receptors as a result of generic stressors from wave energy projects, from the perspective of experts in the field (see Section 3 of main report for a summary of how these priorities were developed).

	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem Interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟥	🟩	🟩	🟥	🟧	🟥	🟧	🟧	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟧	🟩	🟧
B	**Moving devices**	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟩	🟧
C	**Energy removal**	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩							
D	**Chemical release**	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩
E	**Noise and vibration**						🟩	🟩	🟩		🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩
F	**EMF**						🟧	🟧	🟩		🟩	🟧	🟥	🟧	🟩	🟩	🟩		
G	**Boat traffic**														🟧	🟩	🟧		🟩
H	**Lights**													🟩					🟧

🟥 **= High Priority** 🟧 **= Medium Priority** 🟩 **= Low Priority** ⬜ **= No Interaction**

WAVE ENERGY TABLE 1: REGULATORY

Table B-2. Potential importance of generic receptors as a result of generic stressors from wave energy projects, as viewed through the requirements of the federal and state regulatory apparatus (see Section 3 of main report for a summary of how these priorities were developed).

	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem Interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟩	🟩	🟩	🟧	🟩	🟧	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟥	🟧	🟧	🟧	🟥
B	**Moving devices**			🟩	🟩		🟧	🟩	🟩	🟧	🟩	🟩	🟩	🟧	🟥	🟧	🟧		🟧
C	**Energy removal**	🟧	🟩	🟩	🟩		🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟧
D	**Chemical release**	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧		🟧
E	**Noise and vibration**						🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟩	🟧		🟧
F	**EMF**						🟧	🟧	🟩	🟩	🟩	🟥	🟩	🟧	🟩	🟩	🟩		🟩
G	**Boat traffic**						🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧		🟩
H	**Lights**						🟧		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟥

🟥 **= High Priority** 🟧 **= Medium Priority** 🟩 **= Low Priority** ⬜ **= No Interaction**

WAVE ENERGY TABLE 3: STAKEHOLDER

Table B-3. Potential importance of generic receptors as a result of generic stressors from wave energy projects, from the perspective of stakeholders (see Section 3 of main report for a summary of how these priorities were developed).

		Sediment characteristics	Water circulation (waves/currents)	Water Chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions[4]	Benthic invertebrates	Nektonic Invertebrates	Plankton	Resident	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
	Stressor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
A	**Static devices**	⬜	⬜	⬜	🟨	⬜	⬜	🟥	⬜	⬜	🟨	🟨	⬜	⬜	🟥	🟨	⬜	⬜	🟨
B	**Moving Devices**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	🟨	⬜	⬜	🟥	🟨	⬜	⬜	🟨
C	**Energy Removal**	🟨	🟨	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
D	**Chemical Release**	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
E	**Noise and Vibration**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥	🟥	⬜	⬜	🟥	⬜	⬜	⬜	⬜
F	**EMF**	⬜	⬜	⬜	⬜	⬜	⬜	🟥	⬜	⬜	🟥	🟥	🟥	⬜	⬜	⬜	⬜	⬜	⬜
G	**Boat Traffic**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
H	**Lights**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨

🟥 **= Highly Important** 🟨 **= Important** ⬜ **= N/A - Not Reviewed**

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[4] Stakeholders rated cumulative effects of project effects as highly important. Although the use of ecosystem interactions against specific stressors in this matrix is more specific, the stakeholder concern is related to this category and, therefore, is noted here and discussed on page 11.

TIDAL ENERGY TABLE 1: EXPERT OPINION

Table B-4. Potential importance of generic receptors as a result of generic stressors from tidal energy projects, from the perspective of experts in the field (see Section 3 of main report for a summary of how these priorities were developed).

		Sediment characteristics	Water Circulation	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
	Stressor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟨	🟨	🟨	🟨	🟩	🟩	🟨	🟩	🟩	🟨	🟩	🟩		🟩	🟩			🟩
B	**Moving devices**						🟨	🟩	🟩	🟩	🟨	🟨	🟨		🟥	🟥			🟩
C	**Energy removal**	🟨	🟨	🟨	🟩	🟩	🟨												
D	**Chemical release**			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩	🟩			🟩
E	**Noise and vibration**							🟩	🟩		🟩	🟩	🟩		🟥	🟨			🟨
F	**EMF**							🟨	🟩		🟨	🟨	🟥		🟩	🟩			
G	**Boat traffic**										🟩	🟩	🟩		🟩	🟩			🟩
H	**Lights**																		

🟥 **= High Priority**

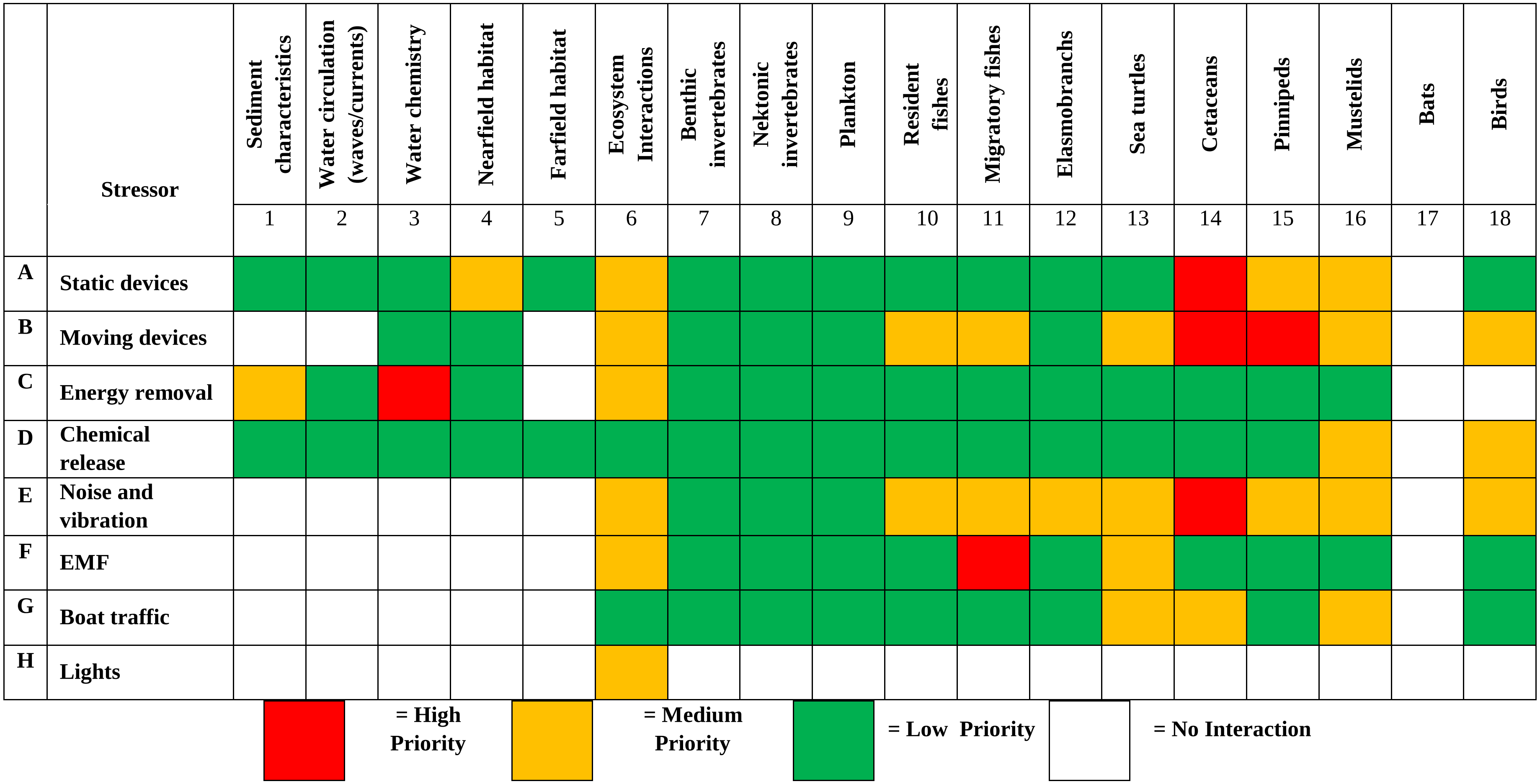
🟨 **= Medium Priority**

🟩 **= Low Priority**

⬜ **= No Interaction**

TIDAL ENERGY TABLE 2: REGULATORY

Table B-5. Potential importance of generic receptors as a result of generic stressors from tidal energy projects, as viewed through the requirements of the federal and state regulatory apparatus (see Section 3 of main report for a summary of how these priorities were developed).



	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem Interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	Static devices	🟩	🟩	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟨	🟨	⬜	🟩
B	Moving devices	⬜	⬜	🟩	🟩	⬜	🟨	🟩	🟩	🟩	🟨	🟨	🟩	🟨	🟥	🟥	🟨	⬜	🟨
C	Energy removal	🟨	🟩	🟥	🟩	⬜	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	⬜	⬜
D	Chemical release	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	⬜	🟨
E	Noise and vibration	⬜	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟥	🟨	🟨	⬜	🟨
F	EMF	⬜	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	🟩	🟥	🟩	🟨	🟩	🟩	🟩	⬜	🟩
G	Boat traffic	⬜	⬜	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟨	⬜	🟩
H	Lights	⬜	⬜	⬜	⬜	⬜	🟨	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜

🟥 **= High Priority** 🟨 **= Medium Priority** 🟩 **= Low Priority** ⬜ **= No Interaction**

TIDAL ENERGY TABLE 3: STAKEHOLDER

Table B-6. Potential importance of generic receptors as a result of generic stressors from tidal energy projects, from the perspective of stakeholders (see Section 3 of main report for a summary of how these priorities were developed).

	Stressor	Sediment characteristics 1	Water circulation (waves/currents) 2	Water Chemistry 3	Nearfield habitat 4	Farfield habitat 5	Ecosystem interactions[5] 6	Benthic invertebrates 7	Nektonic Invertebrates 8	Plankton 9	Resident fishes 10	Migratory fishes 11	Elasmobranchs 12	Sea turtles 13	Cetaceans 14	Pinnipeds 15	Mustelids 16	Bats 17	Birds 18
A	Static devices	⬜	⬜	⬜	🟨	⬜	⬜	⬜	⬜	⬜	🟥	🟥	⬜	⬜	🟥	⬜	⬜	⬜	🟨
B	Moving Devices	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥	🟥	⬜	⬜	🟥	⬜	⬜	⬜	🟨
C	Energy Removal	🟥	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
D	Chemical Release	🟥	⬜	⬜	⬜	🟨	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
E	Noise and Vibration	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥	🟥	⬜	⬜	🟥	⬜	⬜	⬜	⬜
F	EMF	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	🟨	🟨	⬜	⬜	⬜	⬜	⬜	⬜
G	Boat Traffic	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
H	Lights	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜

🟥 **= Highly Important**

🟨 **= Important**

⬜ **= N/A - Not Reviewed**

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[5] Stakeholders rated cumulative effects of project effects as highly important. Although the use of ecosystem interactions against specific stressors in this matrix is more specific, the stakeholder concern is related to this category and, therefore, is noted here and discussed on page 11.

OFFSHORE WIND ENERGY TABLE 1: EXPERT OPINION

Table B-7. Potential importance of generic receptors as a result of generic stressors from offshore wind energy projects, from the perspective of experts in the field (see Section 3 of main report for a summary of how these priorities were developed).

		Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
	Stressor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟥	🟩	🟩	🟥	🟧	🟥	🟧	🟧	🟩	🟧	🟧	🟧	🟧	🟥	🟧	🟩	🟧	🟧
B	**Moving devices**																	🟥	🟥
C	**Energy removal**																	🟩	🟩
D	**Chemical release**	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩
E	**Noise and vibration**						🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟧	🟩
F	**EMF**						🟧	🟧	🟩		🟩	🟧	🟥	🟥	🟩	🟩	🟩	🟧	🟩
G	**Boat traffic**														🟧	🟩	🟧		🟩
H	**Lights**													🟩				🟥	🟥

🟥 **= High Priority**

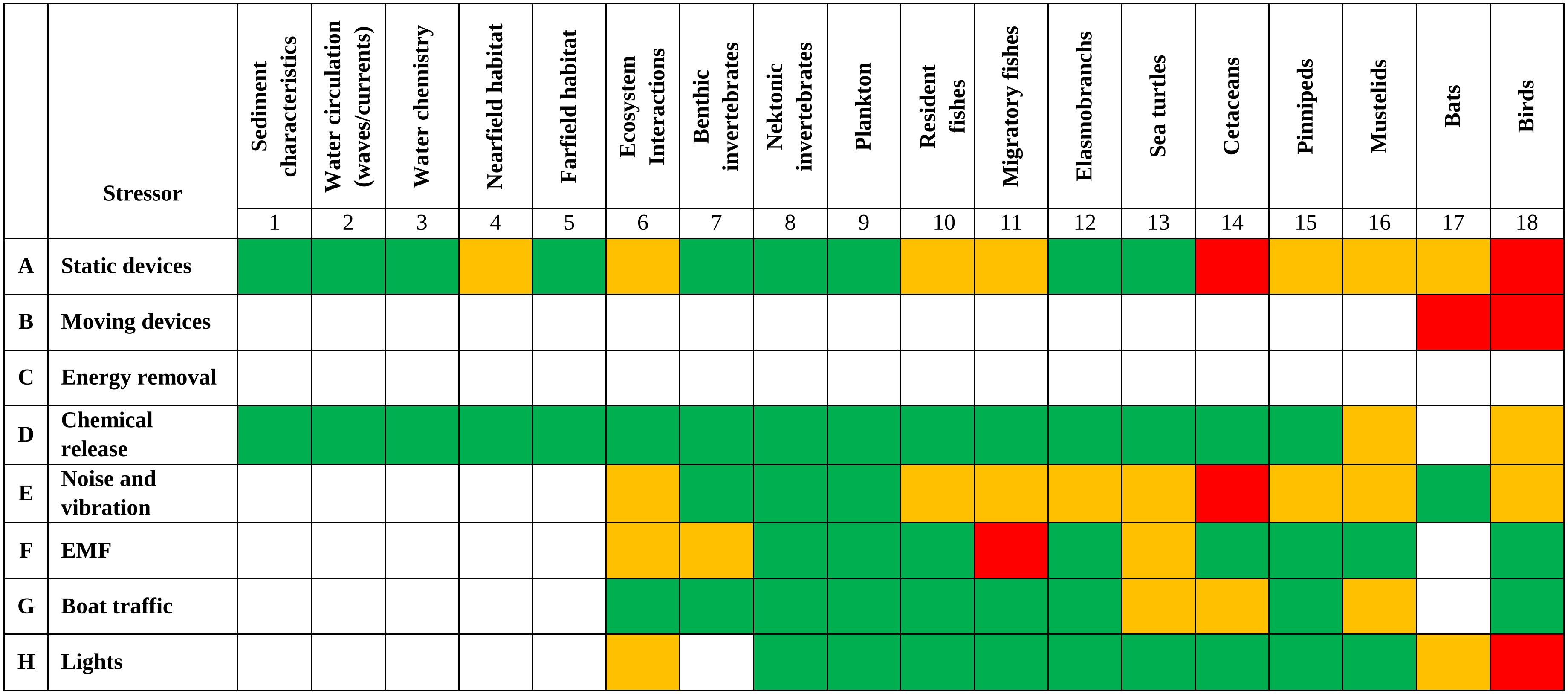
🟧 **= Medium Priority**

🟩 **= Low Priority**

⬜ **= No Interaction**

OFFSHORE WIND TABLE 2: REGULATORY

Table B-8. Potential importance of generic receptors as a result of generic stressors from offshore wind energy projects, as viewed through the requirements of the federal and state regulatory apparatus.



	Stressor	Sediment characteristics	Water circulation (waves/currents)	Water chemistry	Nearfield habitat	Farfield habitat	Ecosystem Interactions	Benthic invertebrates	Nektonic invertebrates	Plankton	Resident fishes	Migratory fishes	Elasmobranchs	Sea turtles	Cetaceans	Pinnipeds	Mustelids	Bats	Birds
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	**Static devices**	🟩	🟩	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟨	🟨	🟩	🟩	🟥	🟨	🟨	🟨	🟥
B	**Moving devices**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥	🟥
C	**Energy removal**	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
D	**Chemical release**	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	⬜	🟨
E	**Noise and vibration**	⬜	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟩	🟨
F	**EMF**	⬜	⬜	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩	🟥	🟩	🟨	🟩	🟩	🟩	⬜	🟩
G	**Boat traffic**	⬜	⬜	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟨	⬜	🟩
H	**Lights**	⬜	⬜	⬜	⬜	⬜	🟨	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥

🟥 **= High Priority**

🟨 **= Medium Priority**

🟩 **= Low Priority**

⬜ **= No Interaction**

OFFSHORE WIND TABLE 3: STAKEHOLDER

Table B-9. Potential importance of generic receptors as a result of generic stressors from offshore wind energy projects, from the perspective of stakeholders (see Section 3 of main report for a summary of how these priorities were developed).

	Stressor	**Sediment characteristics**	**Water circulation (waves/currents)**	**Water Chemistry**	**Nearfield habitat**	**Farfield habitat**	**Ecosystem interactions**[6]	**Benthic invertebrates**	**Nektonic Invertebrates**	**Plankton**	**Resident fishes**	**Migratory fishes**	**Elasmobranchs**	**Sea turtles**	**Cetaceans**	**Pinnipeds**	**Mustelids**	**Bats**	**Birds**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Static devices	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	⬜	⬜	🟨	🟨
	Moving Devices	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	🟥
	Energy Removal	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	Chemical Release	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	Noise and Vibration	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	🟨	⬜	⬜	🟥	⬜	⬜	⬜	⬜
	EMF	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟨	🟨	🟨	⬜	⬜	⬜	⬜	⬜	⬜
	Boat Traffic	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	Lights	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	🟥

🟥 **= Highly Important** 🟨 **= Important** ⬜ **= N/A Not Reviewed**

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[6] Stakeholders rated cumulative effects of project effects as highly important. Although the use of ecosystem interactions against specific stressors in this matrix is more specific, the stakeholder concern is related to this category and, therefore, is noted here and discussed on page 11.

STAKEHOLDER PRIORITIES - CONSTANT CONTACT SURVEY RESULTS

1. For each of the wave energy related interactions listed below, please indicate the level of importance.

	Highly Important	**Important**	**Low Importance**	**Don't Know/Need Info**
Cumulative effects of multiple projects	70%	24%	3%	3%
Cumulative effects of project stressors	56%	35%	4%	5%
Marine mammal interaction/collision with devices and anchoring systems	54%	31%	11%	5%
Effect of noise and vibration on marine mammals	47%	35%	13%	6%
Chemical release related to spills or project coatings	40%	35%	22%	3%
Electromagnetic field effects on sharks and fishes	38%	34%	18%	10%
Effect of anchoring system and electromagentic fields on Dungeness Crab	37%	27%	21%	15%
Effect of noise and vibration on fishes	36%	29%	25%	10%
Change in fish behavior due to the presence of devices and anchoring systems	34%	36%	21%	9%
Change in sediment transport due to removal of wave energy	33%	41%	17%	10%
Change in predator/prey relationship due to presence of devices and anchoring systems	28%	42%	21%	10%
Bird interaction or collision with devices	24%	32%	36%	8%
Changes in wave power	23%	39%	24%	15%
Effect of lighting on the potential bird collision	23%	41%	27%	9%
Pinniped haul-out on devices	18%	37%	27%	18%

2. For each of the tidal energy interactions listed below, please indicate importance.

	Highly Important	Important	Low Importance	Don't Know/Need Info
Cumulative effects of multiple projects	72%	23%	3%	2%
Cumulative effects of project stressors	60%	30%	7%	3%
Marine mammal interaction/collision with devices and anchoring systems	50%	32%	14%	4%
Changes in tidal exchange and water quality due to removal of current energy	45%	34%	18%	3%
Fish interaction/collision with devices	42%	39%	17%	2%
Effect of noise and vibration on marine mammals	40%	40%	15%	5%
Effect of noise and vibration on fishes	38%	34%	20%	8%
Chemical release related to spills or project coatings	37%	32%	27%	3%
Diving bird interaction with device	34%	36%	25%	6%
Electromagnetic field effects on sharks and other fishes	32%	37%	26%	6%
Change in predator/prey relationship due to presence of device(s)	30%	43%	19%	8%

3. For each of the offshore wind related interactions listed below, please indicate importance.

	Highly Important	Important	Low Importance	Don't Know/Need Info
Cumulative effects of multiple projects	65%	27%	3%	4%
Bird collision with rotors	59%	29%	8%	4%
Cumulative effects of project stressors	58%	32%	4%	7%
Effect of lighting on bird collision with rotors	47%	33%	12%	8%
Effect of noise and vibration on marine mammals	39%	45%	11%	5%
Chemical release related to spills or project coatings	38%	29%	29%	4%
Marine mammal interaction with platform and subsurface infrastructure	35%	36%	24%	6%
Electromagnetic field effects on sharks and other fishes	34%	38%	22%	7%
Effect of noise and vibration on fishes	32%	43%	20%	5%
Bird interactions with platform and subsurface infrastructure	28%	41%	26%	4%
Bat collision with rotors	26%	36%	29%	9%

	Number of Response(s)	Response Ratio
Environmental Advocacy Group	13	11.0%
Academic/Research Institute	6	5.0%
Recreational Ocean User	6	5.0%
Commercial Ocean User	9	7.6%
Coastal Citizen	9	7.6%
Industry - Developer/Utility	6	5.0%
Industry - R&D/Professional Services	6	5.0%
Tribal Government	1	<1%

Federal Government	16	13.5%
State Government	12	10.1%
Local Government	6	5.0%
Other	6	5.0%
No Responses	22	18.6%
Total	118	100%

CONSTANT CONTACT SURVEY RESULTS

WAVE ENERGY

Are there any wave energy related interactions not included on the list above that you feel are either HIGH IMPORTANCE or IMPORTANT?

Survey Respondent's Answer	Project Team Response
These projects are insane.Once the corrosive effects of the salt water environment interact with the equipment necssary to generate the extremely high voltage required for such a project the maintenance costs will be prohibitive.	Comment
Long term changes in benthic layer due to mooring anchors &/or blocks and mooring lines with their associated growth and scraping.	**Effect on Nearfield Habitat (Benthic)**
range of variability of marine mammal migration routes; impacts to commercial fishing.	**Effect on Marine Mammal Migration** Socioeconomics
Recreation impacts are not addressed. Ocean/wave recreation is a huge issue on west coast projects. For more information please see the new guide available at http://www.hydroreform.org/news/2011/04/04/guide-offers-strategies-for-addressing-recreation-issues-in-new-hydropower-technologies	Socioeconomics
Visual effect on pristine ocean areas. Crab grounds made unuseable to fishermen and economic impact on communities.	Socioeconomics
Potential benthic substrate and community changes from covering by anchors, deposition of biofouling organisms, aritifical reef effects.	**Effect on Nearfield Habitat (Benthic)**
Need to find out how this could impact Naval training areas that are just off the coast and some are along the coast.	Socioeconomics
Among many other resources, ocean waves contain clean & sustainable & renewable energy. More than ever, we humans need to learn how to safely tap into renewable energy resources so we can start replacing our dependence on dangerous nuclear energy.	Comment
related onshore infrastructure and impacts from same--especially if new transmission distribution facilities needed	Onshore Infrastructure

Ecosystem services should be addressed. The current value of these services, change in these services, and any new services rendered from the wave energy sites. Displaced fishing/crabbing pressure or increased fishing/crabbing pressure near the sites. How this effects the ecosystem.	Socioeconomics
Impacts on sand accretion as they relate to jetties and dredging--increased financial burden on the Federal government Impacts on shipping lane traffic Impacts on the commercial fishing industry--loss of crab or fishery grounds--compensation that accrues to the fishing industry for loss of these sometimes prime areas for extraction activity The defacto creation of a "marine reserve" by wave energy parks and how they might interact with the possible creation of marine reserves and marine protected areas. Examination of wave energy vs. offshore wind energy projects Impacts on recreational fishing Impacts on recreational surfing/wind surfing	Captured in "Changes in sediment transport due to wave energy" Socioeconomics Comment Comment Socioeconomics Socioeconomics
Are the public owned area's, that you are wanting to have exclusive access to, currently being used for recreation purposes (fishing,crabbing,...)? If so, I can forsee a host of problems that will need to be addressed.	Socioeconomics
Impact to shipping/navigation/recreation...ambient noise levels...visual aesthetics...	Captured in "Effect of noise and vibration on fishes an marine mammals" Socioeconomics
The effect of this type of energy on the marine mammals populations can be detrimental to all biological populations. I am so tired of you spending my tax dollars on anything but solor energy. When are you going to quit screwing up the planet? How much is enough, learn to live with less. It is not that hard.	Comment

Not as far as fish and birds are concerned.	Comment
I don't think open ocean wave energy devices will work over the long term. I seriously doubt that they will be able to withstand the forces of nature in that environment. I believe it would be much more practical to integrate wave generators with jetty construction. This would afford easier access for maintenance & repair, provide greater relative protection for the devices, & we wouldn't have to worry about them sinking!	Comment
Does physical or mechanical design of system have potential to trap, harm or kill fish, marine mammals or birds.	Captured in "Marine Mammal and Bird interaction/collision with devices and anchoring systems"
It is very difficult to rank these impacts in a general way, because their importance depends so intensively on the specific project characteristics and its location. This survey seems problemmatic because it is asking for subjective opinions -- we need to conducted phased monitoring of actual projects to determine the importance of many of the impacts.	**Specific technologies and locations are important**
Competition with other users, especially with fishermens.	Socioeconomics
Not sure if this is covered by one of the above, but I would also be concerned about adverse consequences resulting from habitat displacement of marine mammals, turtles and other large marine fauna that may change migratory passage, foraging or other changes in behavior as a result of being confronted with a "maze" of devices that they prefer not to negotiate.	Captured in "Change in fish behavior due to presence of devices and anchoring systems"
potential effects on social, economic and ecological areas for fishing, ocean/beach recreation, etc.	Socioeconomics
Benefits to society.	Socioeconomics
It is difficult to answer the survey without knowing the specific placement of proposed facilities. What does not appear to be considered is habitat avoidance issues. It is possible that species may avoid areas of energy plants and be displaced into other high risk areas increasing their risk of vessel strikes, entanglement, bycatch, etc. Also, cumulative impacts of multiple projects should be clarified and should be inclusive of all offshore development, and not only other wave generating	**Specific technologies and locations are important**

facilities.	
Particle Velocity changes due to the deployment of wave energy converters and potential impact on sensitive fish species.	Captured in "Changes in sediment transport due to wave energy"
Further loss of tourism to the already economically depressed region of Washington State due to tidal energy's potentially unattractive and extensive, man-made structures in the ocean.	Socioeconomics
I believe that to simply band all wave technologies together provides a false outcome. Each wave technology is different depending on where they are deployed, what type of wave device is being assessed (and how each interacts with the environment - there are 7 differing types of wave machine which interacts in different ways - Attenuators, Point Absorbers, Oscillating Wave Surge Converters, Oscillating Water Columns, Overtopping/Terminator devices, Submerged Pressure Differentials or other types that donâ between a very local impact and the wider global impact of global warming. I also belive that the survey is negatively biased and is attempting to categorise the impact (as hard fact) as opposed to attempting to identify the issues and relative importance. Whatever the outcome I doubt it will advance any scientifically robust measurement due to the vagaries of the questions asked.	**Specific technologies and locations are important**
invasive species vectoring	
SAFETY OF OCEAN USERS!!!!!!!!!!!!!!!! EXTENDED TRAVEL TIME AND DISTANCE TO AVOID THEM WHEN IN TROUBLE DUE TO WEATHER OR MECHANICAL BREAKDOWN	Socioeconomics
Change in species complex due to hard structure introduction into sandy, soft-bottom habitat. I feel this is of HIGH IMPORTANCE	**Effect on nearfield habitat**
Artificial reef effects as a positive impact and also interactions with existing sea uses, conflict management and NTZ effects.	**Effect on nearfield habitat**
Recreation and tourism. Asthetics.	Socioeconomics
The questionnaire does not address all the impacts on the ecosystem including the	Socioeconomics

fishermen that currently use the marine waters.	
Sea Turtles	**Effects on Sea Turtles**
Impact on rocky intertidal shoreline. Does the harnessing of wave energy change the amount of wave energy reaching the rocky intertidal? If yes, does that impact rocky intertidal species/communities/habitat structure?	Captured in "Changes in sediment transport due to wave energy"
Interactions between energy devices and marine invertebrates, both sessile and non-sessile, may be IMPORTANT	**Effects on Pelagic and Benthic Invertebrates**
High Importance - How does wave project deny use from existing uses to include reduction in economic return to existing uses.	Socioeconomics
Effects from onshore development in support of the offshore wind and tidal energy projects. This would include construction and other attendant facilities.	Onshore Infrastructure
I feel it highly important that there needs to be a plan including cost for complete removal by the applicant be submitted before a long term license is given to the developer. The financial cost of removal must not be put on the County, State and/or Federal Govt.	Comment

Appendix C

Criteria Thresholds Report

INTRODUCTION

This report is the second in a series in support of the Framework for Protocols for Baseline Studies and Monitoring for Ocean Renewable Energy Project (hereafter “Protocols framework”). The Protocols framework first prioritizes environmental issues, defined as the intersection of key environmental stressors and receptors, for protocol development, and those are reported in the Priorities for Protocol Development, the predecessor to this report. The environmental issues identified in the previous report will be processed through the Protocols framework for specific wave, wind and tidal technologies. This step in the Protocols framework describes how to identify and apply environmental thresholds and criteria (as shown in Figure C-1).

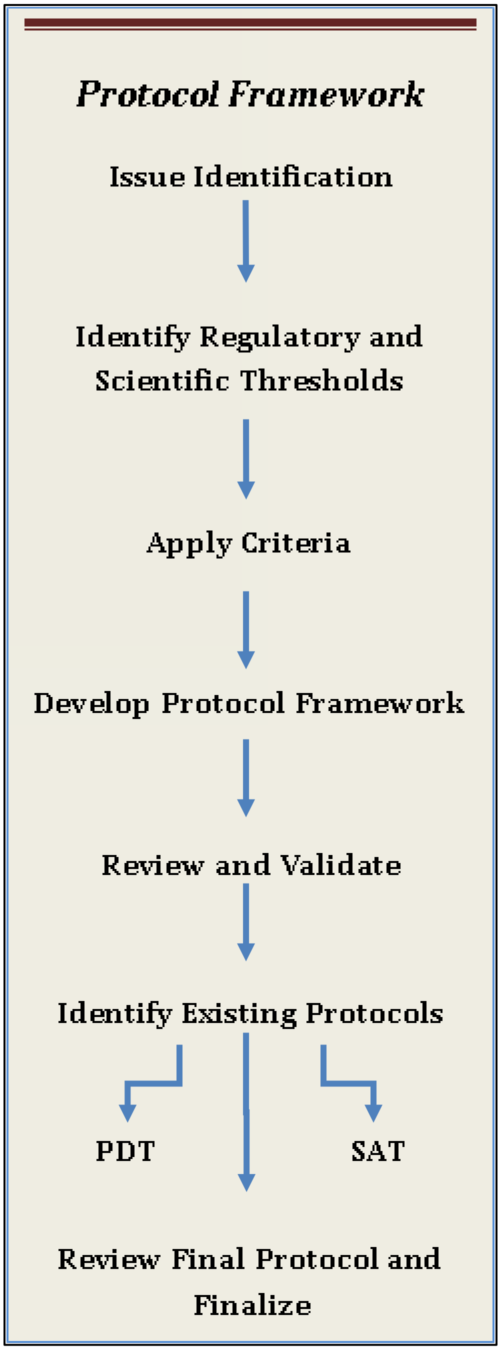

Figure C-1. Steps in Protocols Framework.

PURPOSE AND APPROACH

The purpose of this report is to explain how thresholds and criteria will be applied within the Protocols framework. As stated in the proposal for this project:

> *“Our collective experience and expertise supports developing a Protocols framework because the ecological issues and ways to address them vary by both location and technology; generic monitoring protocols are not likely to be widely applicable. Not only do issues vary, but the criteria and thresholds that issues make “matter” also vary.”*

This report is intended to explain and hone the appropriate working definitions for the use of thresholds and criteria in the Protocols framework, and to demonstrate their application through examples from each of the three ocean energy technologies (wave, tidal, offshore wind). *Next Steps* will point towards the integration of the body of knowledge into the project’s final products.

THRESHOLDS AND CRITERIA

Both thresholds and criteria are widely used concepts in the arena of environmental risk assessment. A *threshold* is commonly defined as the minimum intensity or strength of a signal from some kind of an input to a system that will produce a response or a specified effect (see Appendix A for a more specific definition of the application of thresholds in the context of environmental risk assessment). *Criteria* (or *criterion*) is a term generally defined as a standard of judgment or criticism, or a rule or principle for evaluating or testing. It could also be a set of rules applicable to an action or a decision. In the context of environmental risk assessment, criteria could be a set of rules for how a parameter is measured, or how to choose a parameter to be measured.

Scientific and Regulatory Thresholds As Applied in the Framework

The Protocols framework will employ two very specific applications of the threshold concept:

- Scientific best judgment, and
- State and federal regulatory authorities.

Thresholds may or may not exist for specific environmental issues; in many or most cases they simply do not. As used in both the scientific and regulatory context, a threshold is herein defined as the value of a given metric (or measurement or parameter) that would cause an action to be taken in the management of an ocean renewable energy project. That action could entail a broad array of responses, including repeating the original measurement(s), adding additional measurements or metrics, initiating targeted effects studies, or testing or taking some kind of management action as might be mandated by an adaptive management plan (see Williams *et al*. 2009). It is also important to remember that thresholds for specific projects will be applied in a technology- and site-specific basis.

Scientific Thresholds

Scientific thresholds are used in the context of this project to refer to measurements (or metrics) that the scientific literature states as indicators of step-wise change in the health of natural systems. Establishing scientific thresholds (as well as developing criteria for protocol development) requires an understanding of both stressor and receptor characteristics.

Scientific thresholds for affected individual receptor species may be derived from indirect and/or direct measures, as examples, of:

- Population size;
- Successful reproduction and recruitment;
- Ability to seek and obtain prey;
- Ability to avoid predators;
- Ability to compete successfully for resources;
- Availability of suitable habitat; or
- Behavioral responses or taxes (*i.e*., behaviors) that may place animals at risk for injury or mortality.

Scientific thresholds for the affected quantity and quality of habitat may be derived, as examples, from:

- Measures of extent (areal or volume);
- Scale-related patchiness, or
- Substrate quality.

Scientific thresholds for ecosystem interactions may be derived, as examples, from:

- Measures of species composition;
- community structure and/or function; or
- Measures of ecological processes; or
- When feasible, measures of biological diversity.

Implementation of Integrated Ecosystem Assessments (IEAs; Levin, *et al*. 2007) by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) will greatly assist the development of scientific thresholds. Under the conceptual framework for IEAs, very specific management targets, indicators, and appropriate measurements or metrics will be developed under the area-specific IEAs. A present effort brackets the entire California Current Large Marine Ecosystem (CCLME; Levin *et al*. 2008, 2009;) and evolving ecosystem models will be used to support this management approach (Levin and Schwing 2011).

Finally, it is necessary to recognize the reality that, based on reasons of the difficulty of measuring the characteristics of some stressors (*e.g.*, limits of analytical detection) or receptors (*e.g.*, extreme variability in distribution and abundance), some thresholds may simply not be identifiable.

Regulatory thresholds refer to values, magnitudes of, or changes in measurements at which the applicable federal, state or other regulations require some kind of action to be taken. Regulatory thresholds are based on scientific theory and thresholds where possible. The action to be taken may be prescribed, as required by some laws, or it may be subject to an adaptive management plan. If scientific and/or regulatory thresholds do not exist, the alternative is to apply the principles of adaptive management. The US Department of the Interior has issued a policy and a technical guide for the use of adaptive management (DOI 2008; Williams *et al*. 2009), and FERC's Interagency Task Force on Studies has advised the use of adaptive management to accommodate uncertainty in FERC license conditions (FERC 2000).

Regulatory Thresholds

Regulatory thresholds may be stressor-based or receptor-based. They may be applied either by a measurement or a characteristic of the stressor (*e.g.*, amplitude in the case of sound or concentration in the case of chemical toxics or other pollutants), or by a measurement of a characteristic of the receptor (*e.g.*, behavioral change, mortality, habitat loss, etc.). The examples below will help to illustrate this relationship.

Water quality “criteria” require federal actions to comply with a state’s “water quality standards” as mandated by section 401 of the CWA. Though under the CWA they are termed *criteria*, under the definitions of this Framework, they would be considered *stressor-based thresholds*. So, the EPA-recommended (1988) threshold for pH in marine waters is below 6.5 or over 8.5 pH units (however, states may adopt a different range with an appropriate basis). Another example of a stressor-based threshold would be the 180db harassment level threshold for cetaceans for high amplitude sounds under the Marine Mammal Protection Act (MMPA).

Receptor-based thresholds are more commonly based on predicted or measured changes in populations, communities, habitats or processes as defined by regulatory authorities. Under the ESA, biological opinions developed during Section 7 consultations would provide take limitations for specific listed species. For example, permitted take could be based on harm to a number of individuals, or mortality to a certain percent of a designated population; however, incidental take cannot jeopardize the continued existence of a listed species or result in destruction or adverse modification of species' critical habitat.

Regulatory Stringency

Levels of protection afforded to natural resources under environmental regulations vary widely, depending on the perceived level of risk and the status or ecological integrity of the resources. Many statues and regulations are likely to apply to the development of ocean energy in coastal and open ocean regimes, under the jurisdiction of state and federal regulators; the most stringent are parsed into a four-tiered assessment of the level of protection afforded under tribal, state and federal law as follows (Copping *et al*. 2011):

- **First Tier:** Strict take prohibitions under statues for ESA, MMPA and MBTA, or in combination.
- **Second Tier:** ESA--Moderate take prohibitions; critical habitat protection.
- **Third Tier:** Federal/State CWA--Pollution discharge permits; MMPA--Take prohibitions; MBTA--Take prohibitions.
- **Fourth Tier:** State listed species--State/tribal fishery regulations State/tribal managed species--Take limitations, area closures; Magnuson-Stevens Act (MSA)--Fishery management plans; essential fish habitat. (Note that state endangered species listings and prohibitions could possibly be more stringent than federal in specific situations.)

Harassment under the MMPA is considered “take”, and thus could fall under the First or Third Tier, depending on the status of the population.

CRITERIA AS APPLIED IN THE FRAMEWORK

Specifically, the proposal defines criteria as:

“… characteristics or attributes that address the spatial and temporal requirements of data, including baseline information, meeting regulatory criteria for moving a project forward.”

This project parses environmental interactions of concern for the development of ocean renewable energy into potential interactions between stressors and receptors. Each issue, when placed in the context of a specific technology and a specific site will have criteria that are unique filters for defining protocols that technology and site. The following lists are examples of factors to be taken into account when developing criteria.

Stressor Factors

- **Spatial Scale**: each stressor will have scale factors that establish the near- and far-fields. For example, the scale of noise as a stressor in an aquatic environment is much larger than the scale for electromagnetic fields in an aquatic environment. Appropriate scale factors for stressors will be estimated from prior studies, modeling and other germane literature.
- **Other stressor-specific factors**: for example for noise – range in amplitude; range in frequency; spectra of amplitude and frequency across full range of sea states; intermittency, periodicity or episodicity (may relate to sea states); and other confounding sources of noise, such as that from passing ships.
- **Stressor sources and project phases:** sources during siting, construction, operations and maintenance, and decommissioning.

Receptor Factors

- **Spatial distribution**: for species, for example, distribution of adult populations, migrations, habitat utilization by adults, juveniles and younger life stages.
- **Temporal distribution**: seasonal and interannual cycles of spatial distribution characteristics as above.
- **Vulnerability**: for example, of different life stages, such as vulnerability of invertebrate larvae or propagules to anti-fouling compounds.

Clearly the application of criteria for developing protocols that will address specific priority issues requires a good understanding of the characteristics of both the stressor and the receptor.

EXAMPLES OF THRESHOLDS AND CRITERIA AS APPLIED IN THE FRAMEWORK

The following are examples of how thresholds and criteria are applied under this project to specific technologies deployed in specific regions or sub-regions. There is one example each for wave, wind and tidal technologies deployed in the West Coast Region. The environmental issues used in the examples were outlined in the *Priorities for Protocol Development* report.

Wave Example

Example Technology

The technology chosen for the example is the Ocean Power Technologies *Power Buoy* (Figure 2, at end of section V) deployed on the inner shelf offshore Reedsport, Oregon.

Example Issues

Stressor: Moving devices*Receptor*: Cetaceans *Priority*: Medium
Issue: Cetaceans could collide with moving components of wave energy converters while migrating through and/or feeding in the area.

Stressor: Static devices Receptor: Cetaceans Priority: High
Issue: Cetaceans could collide with static components (anchors, mooring lines) of installations while migrating through and/or feeding in the area.

Stressor: Noise/vibration Receptor: Cetaceans Priority: Medium
Issue: Cetaceans could be harassed by noise generated by wave energy converters while migrating through and/or feeding in the area.

Example Thresholds

Regulatory Thresholds

ESA: Take or injury of one individual; harassment by presence of devices or traffic to devices; harassment by acoustics (Level A =180dB and Level B = 120-160dB).

ESA-listed species: Humpback, blue, fin, sei, sperm, and southern resident killer whale potentially present in project area but have not been observed.

MMPA: Harassment due to noise can be considered take if sufficient effect is observed relative to the population status.

Scientific Thresholds

For species that could occur in project area:

1. Strikes with buoys or mooring lines causing or contributing to population declines; OR
2. Significant proportion of population being affected indirectly by alterations in behavior (avoidance of area resulting in loss of feeding opportunities or increase in migration distances)

MMPA Protected species: Gray, minke, and killer whales, harbor and Dahl’s porpoise, northern right whale, Pacific white-sided, risso and common dolphin have been observed in the project area.

Example Criteria

Stressor Criteria

Determine noise level and frequency of device components; propagation of acoustic emissions of the PowerBuoy system at the project location can be modeled.

Receptor Criteria

Generally, for EACH cetacean species that could occur in the project area, determine:

1. Population parameters (population status and trends, age structure).
2. Seasonal, diurnal, annual distribution.
3. Migration paths (depth/distance from shore)
4. Migration characteristics (depth, speed, sinuosity, other relevant behaviors)
5. Feeding locations.
6. Avoidance/ attraction behaviors.

For this project, gray whales and harbor porpoises may occur commonly enough in the area to be measured.

1. Local population parameters for some species (gray, killer, harbor porpoises) are known.
2. Distributions, migration timing and paths have been characterized in other areas of Oregon coast from at-sea (or aerial) and land surveys – timing and distribution in project areas may be estimated.
3. Feeding locations are known in other areas of Oregon coast from at-sea (or aerial) and land surveys.

Tidal Example

Example Technology

The technology chosen for the tidal energy development example is the Open Hydro *Open Centre Turbine* (Figure 4, at end of section V) deployed at Admiralty Inlet, Puget Sound.

Example Issue(s)

Stressor: Noise and vibration *Receptor*: cetaceans *Priority*: High

Issue: Cetaceans are known to be very sensitive to underwater sound, using acoustic calls and signals for communication and navigation. Underwater Sound supports cetacean swimming, hunting for prey, mating, and reproduction. Noise From rotating tidal turbine rotors produce acoustic output at variable frequencies and amplitude, depending on the rotation rate throughout the tidal cycle. Turbine Acoustic output may disturb cetaceans causing them to alter or abandon normal activities, or may mask cetacean hearing, interfering with communication and navigation.

Example Thresholds

Regulatory Thresholds

- *ESA*: harassment of listed species by acoustics (level A and Level B harassment) of 180dB and 120-160dB, respectively.
    - *ESA-Listed Species*: Southern resident killer whales (*Orcinus orca*).

- *MMPA*: Harassment due to noise can be considered a taking if sufficient injury is inflicted.
    - *MMPA-Listed Species*: orca, harbor porpoises, and occasional sightings of gray whales, minke whales, pilot whales, Dall’s porpoises.

Scientific Thresholds

For species that could occur in the project area:

1. Acoustic output of turbines at or above threshold cetaceans’ hearing.
2. Behavioral changes of cetaceans in the vicinity of turbines.

In this specific case:

1. Measurement of turbine noise in relation to audiograms of species’ hearing.
2. Observations of changes in behavior of cetaceans in Admiralty Inlet, close to turbine field.

Example Criteria

Generally, for each cetacean population that could occur in the project area, determine:

1. Population distribution, age structure, and reproductive rate.
2. Seasonal and diurnal patterns of movement through study area (portion of water body near turbines.
3. Behavior during diving, feeding, resting, and other common activities in study area.
4. Auditory range of each species.
5. Acoustic profile of turbine noise in study area over tidal cycles.

In this project area:

1. Population and behavioral information on Southern resident killer whales (orca), harbor porpoises, occasional visitors like gray whales, minke whales, pilot whales and Dall’s porpoise.
2. Acoustic profile of Open Hydro turbines.
3. Acoustic field in Admiralty Inlet in relation to the acoustic output of turbines.

Offshore Wind Example

Example Technology

The technology chosen for the offshore wind energy development example is the Principal Power *WindFloat* (Figure 3, at end of section V) deployed offshore Humboldt Bay, California.

Example Issues

Stressor: Moving devices*Receptor*: Birds *Priority*: High

Issue: Birds could collide with wind turbines while flying through the area. Birds could also change their behaviors in response to wind turbines, either through avoidance of, or attraction to, turbines (MMS 2009, Hüppop *et al*. 2006).

Stressor: Static devices *Receptor*: Birds *Priority*: Medium
Issue: Birds could collide with wind turbine support towers above the surface of the water (MMS 2009, Hüppop et al. 2006). Birds could also be attracted to support towers for roosting (MMS 2009, Hüppop *et al*. 2006).

Stressor: Lighting *Receptor*: Birds *Priority*: High
Issue: Navigation lights on wind turbines could attract some species of birds, and increase their potential for collision with wind turbines (Nelson et al. 2008, Hüppop *et al*. 2006).

Example Thresholds

Regulatory Thresholds

- *ESA-listed*: Marbled murrelet, short-tailed albatross, snowy plover.
- *State-listed*: None, project outside of state waters.
- ESA-listed or State-listed species could occur in project area: could kill, harass, or injure one individual.

Scientific Thresholds

For species that could occur in project area:

1. Strikes with turbines or support towers causing or contributing to population declines; OR
2. Significant proportion of population being directly killed or injured by strikes with turbines or collision with support towers, or indirectly by alterations in behavior (avoidance of turbines or attraction to towers or lighting).

Types of species that could be monitored for exceeding scientific threshold: alcids, gulls, cormorants, pelicans, waterfowl, storm-petrels, shearwaters, albatrosses, shorebirds:

Example Criteria

Generally, for EACH bird species that could occur in the project area, determine:

1. Breeding locations or colonies
2. Seasonal, diurnal, annual distribution
3. Feeding locations
4. Population parameters (population status and trends, age structure)
5. Avoidance/ attraction behaviors
6. Flight pathways and timing (seasonal migration, daily feeding, weather conditions)
7. Flight characteristics (height, speed, flocking or singular, other relevant behaviors

In this project area:

1. Alcid nesting colony-Castle Rock NWR, Marbled murrelet nesting in RNSP, Snowy plover nesting on local beaches.
2. Distribution known in project area from at-sea aerial and boat seabird surveys
3. Feeding locations known in project area from at-sea aerial and boat seabird surveys.
4. Local population parameters known for some species: marbled murrelet, snowy plover, common murre, cormorant, pelican.
5. Alcids, storm-petrels, shearwaters, albatrosses attracted to lights; Gulls, cormorants, pelicans attracted to structures for roosting; some species may avoid turbines.
6. Limited flight pathways/timing information from at-sea distribution seabird surveys.
7. Limited flight characteristics information from literature.

DEFINITION OF THRESHOLDS IN ENVIRONMENTAL RISK ASSESSMENT

In the scientific arena, t*hresholds* are often described as point in dose-response relationships where the further increase of a dose (*i.e*., a signal from a stressor) will cause a fundamental change in the relationship with the receptor. A very common example of a dose-response threshold is a relationship where response from the receptor is very low until the dose reaches a certain strength, at which point the response from the receptor increases rapidly (see Figure 1). The example below is the ideal, and actual responses may be linear or curvilinear and complex (*e.g*., see Lohse *et al*. in Nelson *et al*. 2008). This concept of thresholds is valuable and is applicable to many measureable attributes of individuals, populations, communities, habitats and ecosystem processes. However, actual thresholds of environmental risk cannot be described by generic relationships: specific thresholds should be based on an understanding of the character and complexities of both the stressor and the receptor.

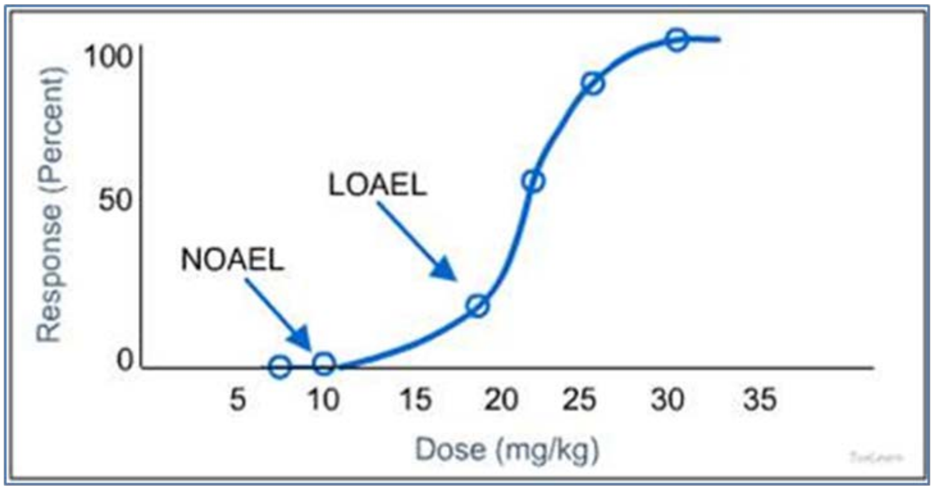

Figure C-2. Hypothetical dose-response curve showing threshold of a response between 10 and 15 mg/kg body weight of a toxic substance.

(NOAEL indicates no observable effect; LOAEL indicates the lowest level of observable effect. Thresholds are also often expressed as Lethal doses for a percent of the population tested; e.g., LD50 for 50% mortality.)

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Appendix D

European Protocols

INTRODUCTION

The purpose of this section is to review the national and international efforts that European countries have made to provide guidance and standard procedures (protocols) for developers and regulatory agencies to follow in the environmental permitting process for renewable ocean energy projects. The development of offshore wind has preceded that of wave and tidal energy development; guidance on the collection of environmental information and processes that entail the application of protocols reflect this greatest focus on offshore wind. In creating a workable framework for U.S. protocols the progress made in Europe has been considered as important background information.

In May 2002, the EU signed and ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change, agreeing to reduce emissions of greenhouse gasses, notably carbon dioxide, from burning fossil fuels (Kyoto Protocol 2005). Following ratification, the European Union and each member state set mandatory objectives to cut greenhouse gas emissions to 80% of 1990 emission level by 2020 by improving energy efficiency and increasing the share of renewable energy production in their energy portfolio. Offshore wind, wave, and tidal energy projects have been explored and developed as a way to meet the European Commission’s strategic goals and to reach Kyoto objectives. Several European countries currently have commercial offshore wind projects as well as pilot wave and tidal projects sited and/or operating in domestic waters.

To speed the implementation of environmentally responsible offshore wind and marine renewable energy projects, European academic institutions, government entities, and international assemblages have worked to identify and eliminate legal, administrative, policy, environmental, and grid infrastructure planning barriers (Roth *et al.*, 2004). One identified way to accomplish this is to increase the “standardization of environmental impact statements.” (EWEA, 2007). Although there has been recognition in Europe that standardized protocols for the collection of environmental effects data would be useful, no system of detailed protocols has emerged. The major efforts aimed at evaluating environmental effects of marine energy and offshore wind development in Europe will be described in the following sections.

EQUIMAR

The most concrete steps taken in Europe towards protocol development falls under the EquiMar program. Beginning in 2007,the European Union funded the EquiMar project with the purpose of developing methods to measure and compare the dozens of tidal and wave energy devices, proposed locations and management systems in development around Europe (EquiMar 2011). EquiMar brought together 60 scientists, developers, engineers and conservationists from 11 European countries to develop protocols and methods of evaluating marine energy technologies and environmental effects. The protocols that proscribe the collection of baseline information and environmental effects monitoring data are written at a very high level, providing guidance on the necessary components for development of protocols but provide no detail.

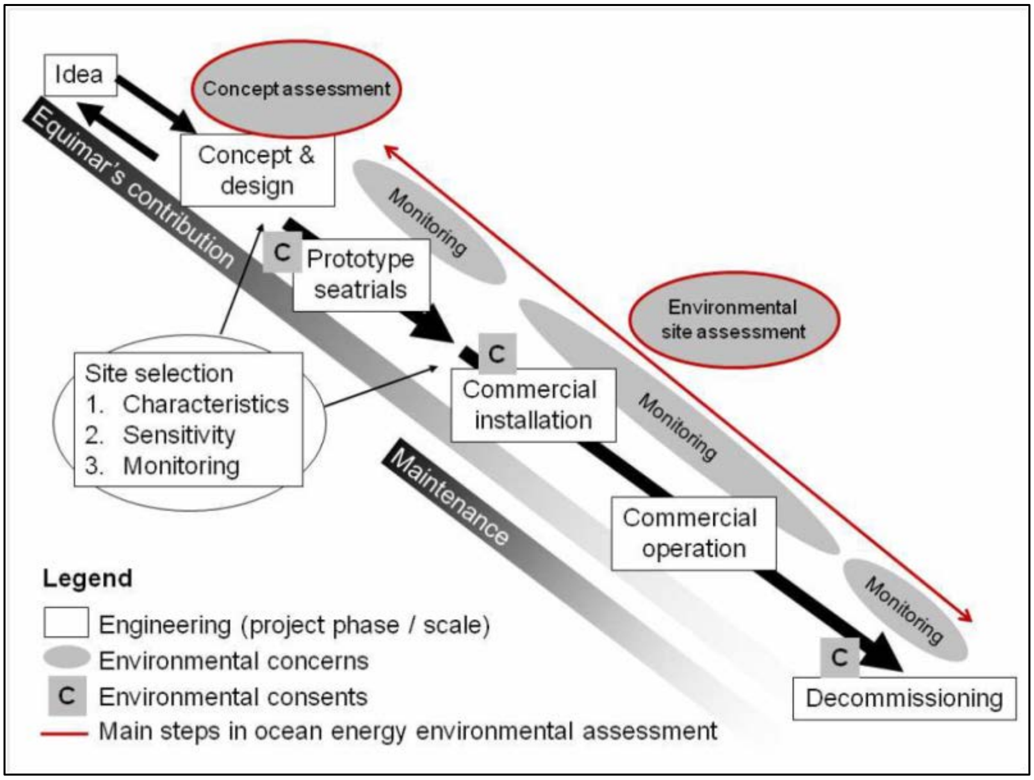

Figure D-1. Scope of the environmental assessment: wave and tidal project phase sequence and environmental concerns during the process (EquiMar 2011).

EU DIRECTIVES FOR MARINE ENERGY DEVELOPMENT

The primary EU directives ensuring that the environmental impacts associated with marine renewable energy projects are appropriately evaluated and managed are the Strategic Environmental Assessments (2001/42/EC) and Environmental Impact Assessment (85/337/EEC as amended).

Other EU Directives that developers need to consider as part of the EIA process include the Marine Strategy Framework Directive (2008/56/EC), which requires national governments to set objectives ensuring that the "introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment," and the two environmental protection directives: the Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EEC).

In each of the EU member states, the EU directives must be enacted into national legislation, for project developers and regulators active in those nations to follow.

COLLECTION OF STANDARDIZED DATA ON ENVIRONMENTAL EFFECTS

Marine energy and offshore wind projects developed in Europe must pass environmental review in their respective countries, including filing environmental reports. Although not driven by standardized protocols, information on the methods used can be gleaned from studies report and data tables for these projects. In Denmark, the offshore windfarms at Horns Rev (http://www.hornsrev.dk) and Nysted (http://www.nystedhavmoellepark.dk) have been studied extensively, and have over 10 years of survey and monitoring information documenting the effects on porpoises, seals, seabirds, fish and the benthos.

The development of the European Marine Energy Center (EMEC) in northern Scotland is a joint enterprise of the EU and the Scottish government. Developed as a full scale tidal and wave test center for marine energy development, EMEC staff have carried out numerous studies to characterize the waters, biota, and habitats of the test sites in order to understand the potential for environmental effects from the devices tested by individual developers; specific protocols have been used at the site, developed in cooperation with the Scottish Association of Marine Sciences (SAMS) and other research groups active at the site (http://www.emec.org.uk/research.asp).

In Spain, the Ministry of Science and Innovation developed the Strategic Outstanding Project on Marine Energy in 2005, joining forces with major Spanish developers to advance the technological development of marine energy converters. In 2010, they focused on the environmental impacts of wave energy converters on the marine environment and produced an early-stage review of likely environmental effects of wave energy to inform project developers, territorial authorities and interested parties (Bald et al. 2010). The document, titled *Protocol to develop an environmental impact study of wave energy converters*, is available at: http://www.azti.es/rim/component/content/article/28.html.

SPECIFIC GUIDANCE ON DATA COLLECTION AND ANALYSIS

The Collaborative Offshore Wind Research Into The Environment (COWRIE) was developed in the UK to provide research on the measurement of environmental effects of offshore wind farms and to develop tools to enable effective monitoring of wand farms, with particular emphasis on monitoring of interactions between birds and offshore wind turbines. COWRIE Ltd is a registered Charity governed by a Board of Directors drawn from The Crown Estate, the Department for Energy and Climate Change (DECC), and the British Wind Energy Association (BWEA). Key documents produced by COWRIE researchers include: *Towards standardized seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the UK.* Report COWRIE-BAM-02-2002, April 2004. http://www.offshorewind.co.uk/Assets/1352_bird_survey_phase1_final_04_05_06.pdf

NATIONAL GUIDANCE

Guidance has been issued by several national governments within Europe to assist offshore wind and marine energy developers and regulators in the assessment and permitting process. Examples include those from Germany and the UK:

Germany

- BSH (Bundesamt für Seeschifffahrt und Hydrographie [Federal Agency for Shipping and Hydrography]). 2007. *Standards for Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment*. http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf

United Kingdom

- Joint Nature Conservation Committee (JNCC). 2010. *Statutory nature conservation agency protocol for minimizing the risk of injury to marine mammals from piling noise*. http://jncc.defra.gov.uk/default.aspx?page=4273
- Cefas (Centre for Environment, Fisheries & Aquaculture Science). 2004. *Offshore Wind Farms – Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements*. http://www.cefas.co.uk/publications/files/windfarm-guidance.pdf
- Defra (the governmental Department for Environment, Food and Rural Affairs) (United Kingdom). 2010. *Strategic review of offshore wind farm monitoring data associated with FEPA license conditions*. http://randd.defra.gov.uk/Document.aspx?Document=ME1117_9388_FRP.pdf

INTERNATIONAL GUIDANCE

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature on September 22, 1992 and entered into force on March 25, 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the UK, and has been approved by the European Community and Spain (OSPAR Commission, 2008). Because many Contracting Parties are pursuing offshore wind projects within their national waters, OSPAR (www.ospar.org) has been active in providing guidance to the development of offshore wind farms:

- OSPAR Commission. 2003: Guidance on a Common Approach for Dealing with Applications for the Construction and Operation of Offshore Wind Farms. Reference Number: 2003-16.
- OSPAR Commission. 2004: Problems and Benefits Associated with the Development of Offshore Wind Farms, ISBN 1-904426-48-4.
- OSPAR Commission. 2005: Guidance on Assessments of the Environmental Impacts of, and Best Environmental Practice for, Offshore Wind Farms in Relation to Location. Reference Number: 2005-02.
- OSPAR Commission. 2006: Guidance on Offshore Wind Farms in relation to Assessments of the Environmental Impacts of Construction and Best Environmental Practice for Construction. Reference Number: 2006-05.

- OSPAR Commission. 2008: Guidance on Environmental Considerations for Offshore Wind Farm Development. Reference Number: 2008-03

UNEP Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) is an inter-governmental organization (IGO) that concerns itself with the impact of climate change and the use of renewable resources on the conservation of wild animal species. The US is not a signatory of the Convention but has signed two Memorandums of Understanding for the conservation of marine turtles and sharks. During ten Conferences of Parties, the 116 parties to the Convention have agreed upon numerous resolutions, many of which apply to the development of marine energy and offshore wind, including:

- Resolution 7.5 Wind Turbines and Migratory Species
- Resolution 8.13 Climate Change and Migratory Species
- Resolution 9.7 Climate Change Impacts on Migratory Species
- Resolution 9.19 Adverse Anthropogenic Marin Noise Impacts on Cetaceans and other Biota

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Appendix E

Summary of Ready to Use Protocols and Protocols Needing Development

Table E-1. Summary of ready to use protocols and protocols needing development taken from the case study interactions.

WAVE		
Technology/Interaction	**Ready To Use Protocols**	**Protocols Needing Development**
Moving/Static Devices and Cetaceans	• Protocols for monitoring distribution and migration in Ortega-Ortiz & Mate (2008) and Ortega-Ortiz and Lagerquist (2009).	• Cetacean census protocols for areas appropriate to wave energy.
Static Devices/Energy Removal and Nearfield Sediment Characteristics	• Sediment collection and analysis • Wave/current observations.	• Improved sediment transport observations and models. • Protocols for measuring factors for model input.
Static Devices/Energy Removal and Benthic Invertebrates (Ecosystem Interactions)	• Existing protocols include coring protocols for surveying infaunal invertebrates and video/dive survey protocols for hard bottom observations.	• No additional baseline protocols need development. • Effects protocols that may need development are those to examine device components themselves for associated invertebrates.
EMF and Multiple Receptor Groups	• Stock assessment baseline protocols developed for other purposes may be applicable. • Effects monitoring protocols will be the same as baseline protocols for determining distributions, migration tracks, and feeding behavior.	• Baseline protocols that need development are those to measure EMF of the WEC system at biologically relevant levels and with relevant characteristics. • Effects monitoring for harassment may need new protocol development.

Noise/Vibration and Cetaceans	• Baseline protocols for monitoring distribution and migration in Ortega-Ortiz& Mate (2008) and Ortega-Ortiz and Lagerquist (2009) and for passive acoustic observations for cetaceans (Mellinger et al. 2007). • Effects monitoring protocols will be the same as baseline protocols for determining distributions, migration tracks, and feeding behavior.	• Baseline protocols to census populations of marine mammals of concern. • Protocols to measure acoustic emissions of the WEC system will need to be refined. • Effects monitoring for acoustic harassment may need new protocol development.

TIDAL		
Technology/Interaction	**Ready To Use Protocols**	**Protocols Needing Development**
Moving Devices and Cetaceans/Pinnipeds	• Baseline population census and characteristics assessment (largely observational, a few satellite-tagged animals). However, population studies have not been performed consistently; repeating these studies will improve estimates. • Effects protocols via video monitoring of OpenHydro devices at EMEC.	• Baseline behavior modeling of marine mammals in locale. • Effects: Improved observational and tagging protocols for all marine mammal species in study area. • Acoustic (and maybe optical) observations of marine mammals interacting with turbine blades. • Stress gauges on blades that register collision with object over a specified weight (may not work on ducted turbine like OpenHydro; more useful for unducted turbines • Description/measurement of what a tidal turbine blade strike would look like on the various marine mammals (as opposed to other injuries).
Noise/Vibration and Cetaceans	• Baseline population census and characteristics assessment (largely observational, few satellite-tagged animals). • Behavioral response to stimuli (effects protocols exist for some species).	• Baseline acoustic measurements of turbines and noise field. • Effects protocols for improved observational and tagging studies for all cetacean species in study area.

EMF and Elasmobranchs	- Baseline stock assessment protocols developed for other locations are likely applicable (NOAA, state fisheries agencies), if they focus on the populations of concern. - Kajiura has effects protocol but cannot be made public yet (proprietary to client) - Laboratory results that indicate sensitivity of shark species to various EMF components at levels resembling those of leaking power cables and tidal turbine rotors (PNNL and Kajiura) - Observations of behavioral changes seen in sharks in vicinity of tidal turbines and power cables (Andrew Gill)	- Baseline behavioral characteristics of shark species in locale. - Effects protocol for characterization of potential EMF field in vicinity of power cables and rotating turbine blades.
Moving Devices and Resident/Migratory Fish	- Baseline stock assessments for fish populations using standard survey methods, including trawling. - No effects protocols available.	- Baseline stock assessment of resident and migratory fish populations using acoustics. - Effects protocols for assessment of presence, depths and biomass of juvenile fish and eggs in locale. - Depth distribution of fish populations. - Behavioral response of fish to turbine blades and wake field behind turbines; use of acoustics, as well as stereo cameras and ROVs, are preferred. - Effect of entrainment of juveniles and larvae on surface of turbine.

Energy Removal and Sediment Transport/Water Quality	• Baseline protocols for numerical modeling methods (FVCOM). • Collection of physical parameters, water quality and sediment transport samples for model validation. • Effects protocols for numerical modeling methods (FVCOM). • Collection of physical parameters, water quality and sediment transport variables.	• Baseline protocols for design and sensitivity of hydrodynamic model to determine water circulation. • Effects protocols for model validation to increase accuracy of estimates of impact on circulation and flushing rates, including more detail close to turbine locations.

OFFSHORE WIND		
Technology/Interaction	**Ready To Use Protocols**	**Protocols Needing Development**
Moving Devices/Static Devices and Birds	• Baseline protocols for seasonal, annual distribution, feeding locations of bird species: • Boat surveys (Tasker et al. 1984, Briggs et al. 1987, Clarke et al. 2003, Spear et al. 2004) • Aerial surveys (Briggs et al. 1987, Camphuysen et al. 2004, Certain and Bretagnolle 2008) • Identify foraging or activity areas, daily movements, and home range size of individual birds: Satellite tracking (Perrow et al. 2006), Radio- tracking (Burger and Shaffer 2008, Mellor and Maher 2008)	• Effects protocol for acoustic monitoring to determine use of project area by vocalizing bird species (protocol being developed by BOEM) • Baseline protocol for Doppler weather surveillance to assess use of project area by migrating birds

Static Devices and Multiple Receptor Groups	- Diel, seasonal, interannual and spatial distribution of pelagic fish and invertebrate communities and biomass of pelagic fish: - Mobile or stationary hydroacoustic surveys (Taylor and Maxwell 2007, Georgakarakos and Kitsiou 2008, Parker-Stetter et al. 2009, Trenkel et al. 2008, Lindeboom et al. 2011). - Ground-truth with mid-water trawl (Lindeboom et al. 2001, Arimitsu et al. 2003), multi-mesh gill net (Boldt and Haldorson 2002, Duffy and Beauchamp 2008), or hook and line sampling (Starr et al. 2010). - Diel, seasonal, interannual and spatial distribution patterns of migratory listed fish: - Telemetry (Erickson and Hightower 2007, Lindley et al. 2008, Block et al. 2010, Payne et al. 2010) - Effects protocols for the artificial reef effect: - Fish communities evaluated with hydroacoustics (Wilson et al. 2003, Doray et al. 2008) to determine if biomass associated with hard structure on the bottom (note will likely take some time for species to recruit to new habitat).	- Baseline protocols for visual and acoustic cameras (Somerton and Glendhill 2005, Shortis et al. 2007) - Acoustic-optical systems (Ryan et al. 2009) - Mobile and stationary acoustics (protocol being developed by Horn et al. funded by BOEM). - Passive acoustic monitoring for sound-producing species (Širović et al. 2009) - Effects protocols for autonomous underwater vehicles for acoustic, oceanographic, visual, and telemetry monitoring) (Fernandes et al. 2003). - Visual and acoustic cameras (Somerton and Glendhill 2005, Shortiset al. 2007) - Acoustic-optical systems (Ryan et al. 2009) - Mobile and stationary acoustics (protocol being developed by Horn et al. funded by BOEM). - Passive acoustic monitoring for sound-producing species (Širović et al. 2009). - Autonomous underwater vehicles for acoustic, oceanographic, visual, and telemetry monitoring) (Fernandes et al. 2003) - Effects

Static Devices and Multiple Receptor Groups	• If/when biomass observed, ground-truth species composition using visual surveys (camera/video surveys with ROV, SCUBA, submersible); resident fish and epibenthic invertebrate species composition, size and relative abundance using hook and line (Starr et al. 2010), visual surveys (see baseline on visual surveys, also Dempster 2004, Wilhelmsson et al. 2006), trapping (Terrill et al. 2009), baited video (Shortis et al. 2007). • FAD effect: • Resident fishes, migratory fishes, nektonic invertebrates, and elasmobranchs use hydroacoustics (stationary or mobile) (Wilson et al. 2003, Doray et al. 2008) or acoustic cameras to determine if biomass is associated with hard structure in the water column/on the surface • If biomass is observed, ground-truth species composition using visual surveys (camera/video, ROV, SCUBA, submersible) • Species composition, size and relative abundance using multi-mesh gillnets, mid-water trawl (if possible given mooring lines) • Telemetry for behavior, residency time of migratory species such as green sturgeon, adult salmon, sharks (Winters et al. 2010)	

Static Devices and Multiple Receptor Groups	• Changes to diel, seasonal, interannual and spatial distribution patterns of soft-bottom fish and epibenthic invertebrates:Trapping (Terrill et al. 2009) • Epibenthic trawling (Davies et al. 2001, Curtis and Coggen 2007, Terrill et al. 2009, Lindeboom et al. 2011, Trippel 2011). • Visual surveys (diver/diver operated video, towed video, ROV) (Somerton and Glendhill 2005, Yoklavich and O'Connell 2008, Pacunski et al. 2008, Love et al. 2009, Martin and Lowe 2010). • Predation: • Gut content analysis of predatory fish to determine diet and predation on listed fish species (Boldt and Haldorson 2002, Nairn et al. 2004, Duffy and Beauchamp 2008, Jaquemet et al. 2011).	

Moving Devices and Bats	• Baseline protocols for acoustic monitoring to detect bats in project area (Kunz et al. 2007). • Night-vision observations with night-vision goggles, scopes, infrared or thermal cameras to view flight behavior (Gauthreaux and Livingston 2006, Kunz et al. 2007, Rodrigues et al. 2008). • Marine radar to assess flight characteristics (Kunz et al. 2007). • Effects protocols for acoustic monitoring to detect bats in project area (Kunz et al. 2007). • Night-vision observations with night-vision goggles, scopes, infrared or thermal cameras to view flight behavior (Gauthreaux and Livingston 2006, Kunz et al. 2007, Rodrigues et al. 2008). • Marine radar to assess flight characteristics (Kunz et al. 2007).	• Effects protocols for acoustic monitoring for offshore wind being developed by BOEM. • Radar for birds and bats for offshore wind projects. • Effects protocols for acoustic monitoring for offshore wind being developed by BOEM • Radar for birds and bats for offshore wind projects

Static Devices/Boats and Sea Turtles	• Baseline protocols for aerial surveys to evaluate seasonal, annual distribution of sea turtles (Benson et al. 2007) . • Satellite tracking to determine individual movement and use of project area (Koyayashi et al. 2008, Benson et al. 2011). • Effects protocols for aerial surveys to evaluate seasonal, annual distribution of sea turtles (Benson et al. 2007). • Satellite tracking to determine individual movement and use of project area (Koyayashi et al. 2008, Benson et al. 2011). • Acoustic cameras to view interactions between sea turtles and underwater structures.	• Baseline protocols for high definition aerial surveys (Thaxter and Burton 2009, protocols being developed by BOEM) to assess sea turtle distribution/ density. • Effects protocols for high definition aerial surveys (Thaxter and Burton 2009, protocols being developed by BOEM) to assess sea turtle distribution/ density.

Appendix F

Linkages to Coastal and Marine Spatial Planning

INTRODUCTION AND CONTEXT

The primary West Coast Environmental Protocols Framework report has identified baseline and monitoring protocols necessary for a renewable ocean energy project (wind, wave or tidal), given that the specific technology and site for that project are known. This information may support other ocean management efforts currently underway as well, including Coastal and Marine Spatial Planning (CMSP), also called ocean planning, and the Integrated Ocean Observing System (IOOS) program in the United States.

This brief report will summarize the state of CMSP implementation and the IOOS program, identify potential linkages and/or relationships, and make some conclusions about the incorporation of baseline and monitoring data in support of regional CMSP. It will also make some conclusions about planning for incorporation of these data into the regional Ocean Observing Systems. As the Project is focused on the US West Coast region, examples are drawn from this region.

COASTAL AND MARINE SPATIAL PLANNING

Coastal and Marne Spatial Planning (CMSP) is a tool for accomplishing Ecosystem-Based Management (EBM). The paradigm for, and implementation of, CMSP have developed rapidly since publication of the United Nations Guidebook to CMSP in 2009 (Ehler and Douvere 2009). In December 2009, the Council on Environmental Quality released its *Interim Framework for Effective Coastal and Marine Spatial Planning* (Interagency Ocean Policy Task Force 2009), thus establishing the beginnings of a national policy on the implementation of CMSP. The CEQ then released the final recommendations of the Interagency Ocean Policy Task Force in July 2010 (CEQ 2010). That report defined and described CMSP as follows (CEQ 2010):

"CMSP is a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. CMSP identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives. In practical terms, CMSP provides a public policy process for society to better determine how the ocean, coasts, and Great Lakes are sustainably used and protected - now and for future generations."

Further, the July 2010 recommendations established EBM and CMSP as the number one and two national priority objectives. Finally, in February 2011, the National Ocean Council reported out on the legal authorities for CMSP in the United States. This CMSP mandate did not create any new authorities.

ESSENTIAL ELEMENTS OF THE CMSP PROCESS

- Identify Regional Objectives
- Identify Existing Efforts that Should Help Shape the Plan throughout the Process
- Engage Stakeholders and the Public at Key Points throughout the Process
- Consult Scientists and Technical and Other Experts
- Analyze Data, Users, Services, and Imports
- Develop and Evaluate Alternative Future Use Scenarios and Tradeoffs
- Prepare and Release a Draft CMS Plan with Supporting Environmental Impact Analysis Documentation for Public Review
- Create a Final CMS Plan and Submit for NOC Review
- Implement, Monitor, Evaluate, and Modify (as needed the NOC-certified CMS Plan

Figure F-1. Essential elements of the CMSP process (source: Interagency Ocean Policy Task Force 2009).

While the National Ocean Council represents 27 entities of the federal government, the National Oceanic and Atmospheric Administration (NOAA) has the principal role in implementing CMSP through the Office of the Undersecretary for Oceans and Atmosphere. During FY 2010 NOAA established a team to give technical support related to data and tools development, and the agency has mandated the creation of a National Information Management System (NIMS) by September 2011. Work is ongoing in four NIMS themes (Wahle 2011):

- Functional requirements and conceptual design;
- National and regional scales;
- Core information needs; and
- Data standards and governance.

It is the fourth theme, data standard and governance, that is directly related to the Framework Project. However, the implementation of CMSP at the national level is a multi-year process that has only recently begun, and federal funding for regional capacity has been delayed. For this reason, any near-term connections between CMSP and NIMS related work will not likely be started prior to the completion of the Framework Project. The Framework Project will certainly be used in the CMSP effort. For example, the federal government agencies have stated their intention of incorporating 100% on non-classified data into NIMS by 2015 (Vandergraft 2011). Hence, conclusions in this report are necessarily limited to conceptual approaches and are general in nature. They will key on the development of the Regional Governing Bodies' programs and capacities; on the US West Coast these will be developed through the West Coast Governors' Agreement on Ocean Health (WCGA).

STATUS OF CMSP ON THE US WEST COAST

The states of Washington, Oregon and California, the member states of the WCGA, are all in differing phases of the implementation of CMSP. The state of Washington has developed a set of CMSP recommendations through the Washington Ocean Caucus , but no activity has been funded or initiated. The state of Oregon is actively working, in response to a 2008 Executive Order from then-Governor Kulongoski to revise the state's Territorial Sea Plan to include provision for renewable energy siting through CMSP. Concurrently, existing ocean uses and high value ecological habitats offshore Oregon are being mapped. Oregon also recently initiated a marine reserves program. The state of California established a marine reserves and marine protected area program with its Marine Life Protection Act (MLPA) in 1999, and in 2004 conceived the MLPA Initiative for completion of its marine reserves network. Each state has an ocean atlas GIS program in place to accommodate, manage and communicate marine geospatial data. California and Oregon are also linked to MarineMap, a program designed to provide decision support of marine spatial planning, and Washington's linkage is pending.

The WCGA does not have an Action Coordination Team (ACT) directly tasked with CMSP. However, the issue of data needs is addressed by one of the six major goals of the Alliance: *expanded ocean and coastal scientific information, research, and monitoring*. Additionally, WCGA ACTs directly address Renewable Ocean Energy development and Integrated Ecosystem Assessments (IEAs; see brief discussion of the IEA role below).

The Framework Project is accessing and using information that has been gathered through both California and Oregon planning processes, where appropriate. It is anticipated that any Framework Project outcomes can be incorporated into state planning processes will be upon completion of the Framework Project report.

REGIONAL OCEAN OBSERVING SYSTEMS

The United States has 11 regional nodes in the national Integrated Ocean Observing System (IOOS) program (Figure F-3). The US West Coast (focal point of the Project) has three regional ocean observing organizations: the Northwest Associated Network of Ocean Observing Systems (NANOOS), the Central and Northern California Ocean Observing System (CeNCOOS) and Southern California Coastal Ocean Observing System (SCCOOS). The blueprint for IOOS capacity (US IOOS Office 2010) illustrates the flow of data into regional and national OOS data assembly centers and archives (Figure F-4).

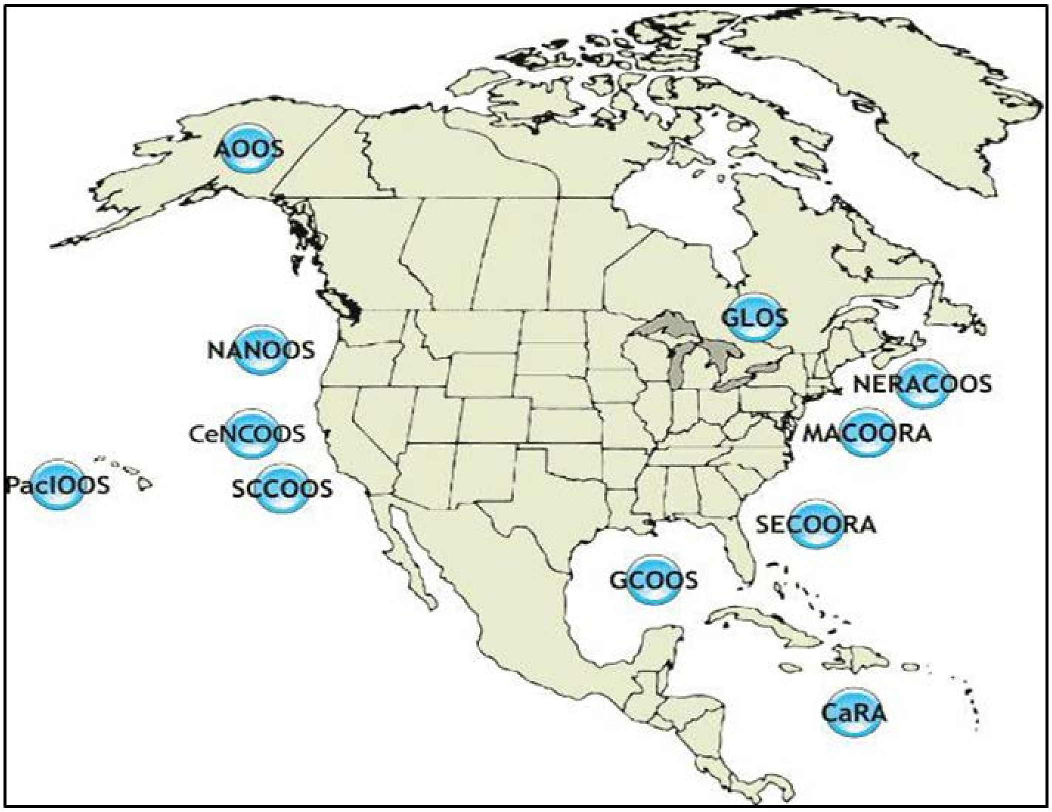

Figure F-2. Names (acronyms) and geographic locations of the United States' 11 regional ocean observing nodes (source: NOAA's IOOS web site).

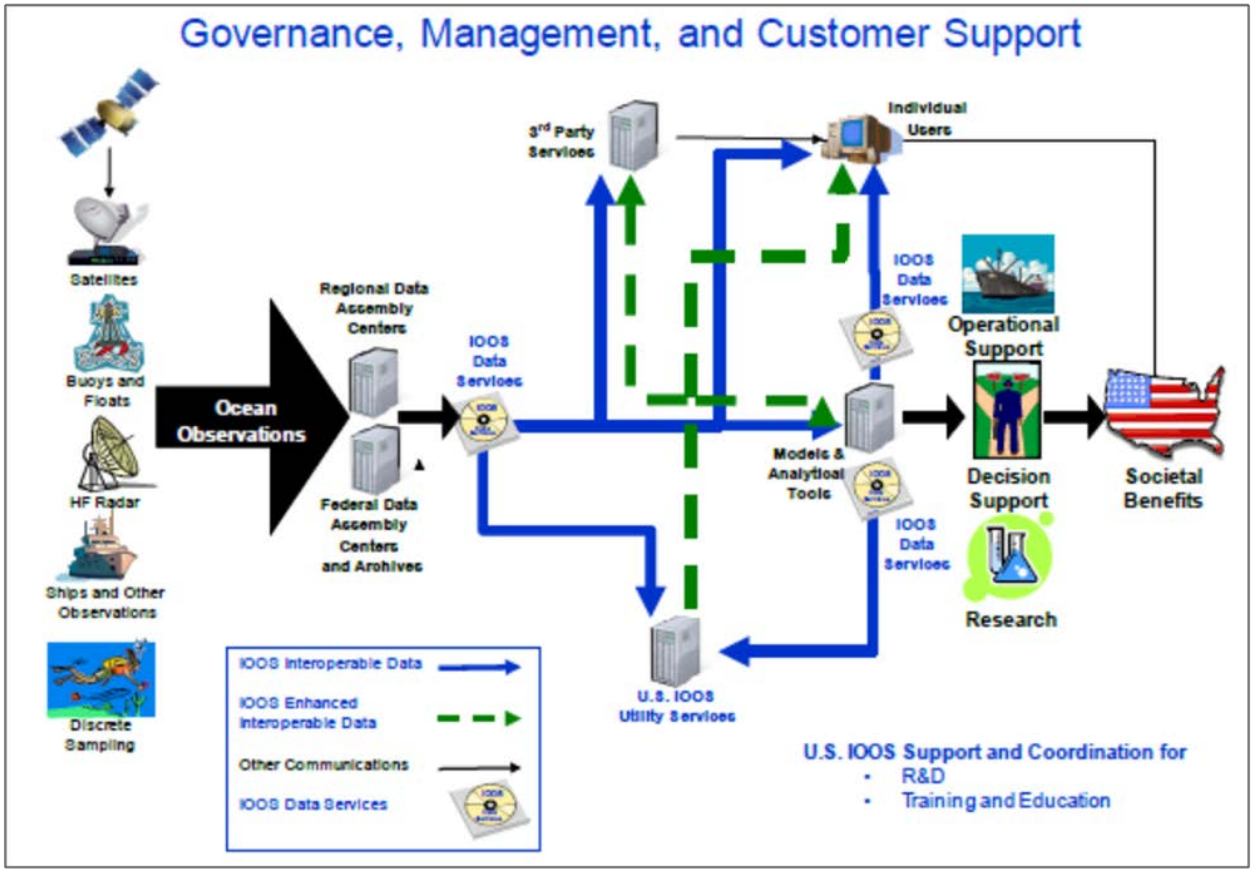

Figure F-3. High level view of data flow through US IOOS functional subsystems in response to end-user needs/requirements (source: US IOOS Office 2010).

The Pacific Coast OOSs, including representation from Canada, have also formed the Pacific Coast Ocean Observing System (PaCOOS), whose Board of Governors is drawn from state and federal agencies and academe. PaCOOS' stated purpose (in its charter) shows the integrative and ecosystem focus of the system:

> The purpose of the organization shall be:
>
> a) To collaborate with the Regional Observing Systems, managed by IOOS Regional Associations, and similar systems in Canada and Mexico to create an integrated Ocean Observing System for the California Current Ecosystem of Pacific Coast of the US.
>
> b) To provide the ecosystem information required for ecosystem-based stock assessments, biological opinions and other science-based management decisions for Pacific coast fishery resources, threatened and endangered species, protected mammals, turtles and living marine resources observed under state-federal agreements.
>
> c) To forecast the consequences of fisheries removals and other anthropogenic effects, climate variability and climate change on the components of the California Current Ecosystem.

d) Improve understanding and prediction of effects of major environmental and climate events as El Niňo and climatic regime shifts on the productivity of natural resources.

e) To advance the technologies for observing and assessing populations of marine fish, mammals, and turtles.

This last charge (e) also makes clear that the regional OOSs may be expected to work bottom up, as well as top down, and may be involved in the actual development of technologies and protocols for environmental measurements.

CMSP, ADAPTIVE MANAGEMENT AND INTEGRATED ECOSYSTEM ASSESSMENTS

NANOOS is actively planning for CMSP integration. It has identified the following short-term products and tasks related thereto (Newton *et al*. 2011): 1) strengthen partnerships via shared work; 2) provide data for compilation, synthesis and analysis; 3) facilitate regional-national data interoperability via standards-based regional data catalogs, data access; and 4) provide regional access to monitoring data through focused applications.

Other closely related EBM tools of interest in the context of CMSP include DOI's approach to Adaptive Management (*e.g.*, Williams *et al*. 2009) and NOAA's approach to Integrated Ecosystem Assessments (IEAs; Levin *et al*. 2008). Common features among the three tools include:

- Multi-sector management;
- Specific management targets or goals;
- Iteration over time; and
- A focus on gradual refinement of scientific observations to refine management.

As CMSP is implemented, it will be necessary for agencies and practitioners to work across these tools and to integrate their use. This will involve addressing DMAC issues and challenges.

CONCLUSIONS

Implementation of ecosystem-based management in the ocean relies on gathering and managing relevant scientific data and information. Coastal and Marine Spatial Planning continues to be in great state of flux, as well as having disparate implementation among the states as of 2011. Hence, only general conclusions may be drawn towards the specific linkages between data developed by environmental baseline and monitoring protocols and CMSP.

The Framework Project intends to supports CMSP and the International Ocean Observing System by supporting current data collection and analysis efforts. First of all, CMSP relies on good data. The protocols framework project will define protocols for developing baseline data and therefore be useful in the development of accurate data to support CMSP. Secondly, CMSP is a policy and planning effort. The protocols framework project will help support further development and evaluation of ocean renewable energy, one of the key elements to be considered in CMSP.

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GLOSSARY

__Note__: These definitions are intended only to address the use of the words in the context of their appearance in this document.

Accelerometer – An instrument designed to sense motion or a change in motion, generally based on the principle of inertia.

Active Acoustics – Sound energy is directed from an instrument underwater in order to bounce off organisms or structures by measuring the timing and intensity of the return signal. Various configurations of active acoustic devices are called sonar, multibeam, splitbeam, and side scan. Much as an optical camera can provide a visual picture of an object, acoustic cameras can provide an acoustic picture of underwater objects, including organisms.

Advect – To transport by fluid motion, for example plankton advected by an ocean current.

Alcid – A family of seabirds that includes the auks, murres and murrelets, puffins and guillemots.

Ambient – Background signals or stressors in the environment.

Adaptive Management – An approach to natural resource management that involves evaluating the results of management actions and modifying subsequent actions.

BACI Approach – An acronym for *Before-After-Control-Impact*, a sampling design approach to evaluate potential ecological impacts by collecting data in one or more control and impact locations both before and after a potential impact begins.

Backscatter – The diffuse reflection of waves, particles, light, sound, or radiation. For example, acoustic backscatter can be used to produce high resolution imagery of benthic habitats (e.g., types of substrates, bathymetry, roughness).

Bacterioplankton – Extremely small sized, but important, marine plankters that include the bacteria and bluegreen algae (cyanobacteria).

Barotrauma – Injury or death to an organism that is caused by a rapid and extreme change in pressure.

Baseline – Pre-project conditions; the studies that establish pre-project conditions.

Beam Trawl – A bottom trawling device that is given its width by a horizontal, solid bar.

Benthic – Living on or in the substrate at the bottom of the water column.

Benthos – The biota living on or in the substrate at the bottom of the water column.

Bioaccumulation – The tendency for some chemicals, especially toxics, to increase at higher trophic levels in the food web.

Biofouling – The buildup of fouling community organisms, generally on artificial structures.

Bioindicator – A species that is sensitive to specific pollutants or stressors and used to indicate their presence.

Bioturbator – An organism that mixes sedimentary substrates through feeding or burrowing processes.

Bycatch – An organism that is captured by any method of fishing or scientific sampling, but is not the target species or group.

Cetaceans – The group of marine mammals that includes both the baleen (mysticetes) and toothed whales (ondontocetes).

Community – A community is an assemblage of living organisms found in a specific habitat. The community is limited by the physical, chemical and biological processes that define the habitat. Changes in the defining processes may lead to changes in the community structure.

Conspecifics – Organism of the same species.

Control Area – A Control Area has similar physical and biological attributes to the experimental area of interest and lies in proximity to the experimental area, but is not directly subject to the influence of concern, most often a human activity.

Criteria – Characteristics or attributes that address the spatial and temporal requirements of data, including baseline information, meeting regulatory requirements for moving a project forward.

Cut-in Speed – The current or wind speed at which a tidal or wind energy device, respectively, is designed to begin to move and generate electricity.

Data Analysis – In the context of environmental monitoring protocols, this is the manipulation and interpretation of environmental data to yield metrics or statistics that demonstrate the presence or absence of an environmental effect.

Delphinids – The family of cetaceans that includes the dolphins and killer whales.

Demersal – Large organisms such as fishes or crabs that live near or on the sea floor.

Derelict Fishing Gear – Fishing gear such as pots, traps and nets that have been lost at sea but may continue to cause mortality to certain species or groups of animals, typically through entanglement or capture.

Diel or Diurnal – Once a day; refers in this context to patterns of movement like diel or diurnal vertical migrations of plankton or fish.

Ecological Process – Any physical, chemical or biological process that has an effect on individuals, species, communities or habitats.

Effect – An effect is a change in the status of an environmental receptor caused by an environmental stressor.

Electric Dipole Moment – A normalized way of describing the source power, for example the intensity of a transmitter. Transmitted electric fields are the product of the length of the dipole and the electric current running through the dipole.

Elasmobranchs – Fish species with skeletons of cartilage. This includes primarily sharks, skates and rays. Many elasmobranchs are able to sense weak electric fields.

Entrainment – To be drawn into, and then carried or swept along with a current, plume, or intake water.

Epibenthic – Characterizing bottom-dwelling animals that live on the surface of the bottom substrate.

Euphausiids – A group of marine crustaceans, often termed krill; an important food source for forage fish and baleen whales.

Exposure – The intersection of a stressor with a receptor in space and time. Exposure, or lack thereof, can be demonstrated by environmental studies, or exposure can be assumed to exist if the appropriate exposure studies are infeasible or too expensive. If exposure is demonstrated or assumed, effects studies may be warranted, or a Worst Case Scenario for effects may be assumed.

Farfield – In the context of this report, far-field refers to habitat or physical environment beyond the immediate vicinity of the marine renewable energy devices, where effects may not be directly observable but nonetheless occur. It is difficult to assign a specific distance, but the kinds of effects that may occur in the far-field would include changes such as sediment size or transport due to reduction of wave or tidal energy; changes in tidal flow at considerable distance from the tidal renewable energy installation that may lead to farfield changes in water quality; and downstream recruitment of organisms that may settle on devices but otherwise not be present in the area of the marine renewable energy device.

Habitat – A habitat describes the place where organisms live; certain groups of organisms (*i.e.*, a community or communities) often characterize certain habitats. Habitats include both biotic (living) and abiotic (nonliving) components.

Heterotroph – Heterotrophs are consumers of organic material as they cannot generate energy or biomass via photo- or chemosynthesis.

Hydrophone – An underwater acoustic listening device that can be recorded to assess underwater sound.

Impact – The term impact is used in this report to refer to a substantial environmental effect.

Infauna – Bottom-dwelling animals that live within the bottom sediments.

Individual – A single individual of a species or a population; environmental effects may be shown, for example, by mortality or changes in behavior at the individual level.

Isobath – A line on a chart that indicates a contour of equal bottom depth.

Local – In the context of environmental monitoring protocols, this is the finest spatial scale of an environmental stressor; synonymous with nearfield.

Macroinvertebrates – invertebrates that are large enough to be seen by the unaided eye and which can be retained by a U.S. Standard No. 30 sieve (0.595 mm), and that live at least part of their life cycles within or on available substrates in a body of water.

Magnetic Dipole Moment – The charge of the magnetic field in time and distance.

Measurement – In this context, any environmental baseline or effects monitoring sample, taken with any remote or *in situ* methodology.

Mesocosm – An experimental enclosure or controlled environment that is considered large enough to avoid or minimize the scale effects of laboratory experiments.

Metric – A parameter (sampled directly or derived from a series of measures or indices) that is used in characterizing environmental condition or effects.

Micronekton – The micronekton are a taxonomically diverse group of organisms including juvenile and adult crustaceans, cephalopods and fishes between 2 and 10 cm in size that are active swimmers but that are too small to be sampled effectively by larger mesh nets and trawls.

Migratory Fish – Fish that follow predictable movements through the environment during their life cycles.

Mitigation – An action taken to prevent, avoid, or in response to, an ecological impact.

Multibeam – A subset of active acoustic devices that records a swath of sonar measurements normal to the path of movement (i.e., to port and starboard of a moving vessel). In multibeam surveys a broad acoustic pulse is transmitted such that multiple points in a line perpendicular to the heading of the ship are plotted simultaneously to provide accurate depths over a large area.

Mysids – A group of crustacean invertebrates that forms swarms near the sea floor and is important forage for fish, birds, and cetaceans.

Mysticetes – The baleen whales.

Mustelids – Carnivorous mammals of the family Mustelidae, including weasels, minks and otters.

Nearfield – The habitat or physical environment over which perturbations from ocean renewable device operations are directly observable, and may be readily differentiated from other natural or anthropogenic perturbations; depending on the stressor, the distance from the device that would be considered nearfield ranges from a few meters (for underwater visual stimuli), to within tens of meters (for hydrodynamic disturbances from rotors or support structure), or to within hundreds of meters (for acoustic stimuli).

Nekton – Water column (i.e., pelagic) organisms larger than 10 cm that swim under their own power and are not at the mercy of the ocean currents.

Odontocetes – The toothed whales and dolphins.

Otter Trawl – A bottom trawling device that is given its width by a pair of "otter boards" that stretch the net by virtue of their hydrodynamic drag when in motion.

Parameter – A measurement or a metric produced by, or utilized in, environmental monitoring.

Pelagic – An organism living in the water column; the water column habitat.

Pinnipeds – A group of marine mammals comprised of walruses, seals and sea lions.

Piscivore – An organism that principally consumes fish as a food source.

Plankton – Water column (i.e., pelagic) organisms that have weak locomotion, if any, with their distribution largely at the mercy of the ocean currents and water density. Plant and animal plankton (phytoplankton and zooplankton, respectively) are generally very small.

Polyp – The life stage of a Cnidarian during which it is attached to the substrate, as opposed to the free floating (medusa) stage that is called a jellyfish.

Population – Organisms of a single species that inhabit a habitat or region. Under the Endangered Species Act, a population at risk may be a genetically isolated Distinct Population Segment.

Power Analysis – In the context of environmental monitoring, an analysis of statistical variance that determines the sample size needed to demonstrate significant change in a measurement or parameter.

Protocol - A written, accepted methodology for data collection and analysis that addresses specific environmental issues, species, habitats, or stressors of interest.

Protocols Framework – As developed in this document, a process to address environmental monitoring needs by: identifying key issues to be evaluated; determining the data needed to evaluate those issues; and defining the protocols needed to collect and analyze the data.

Receptor – A characteristic of the environment, generally an ecological entity or physical process, in which change from stressors can result; includes individuals, populations, communities, habitats and ecological processes.

Redox Depth – The depth in the bottom sediments substrate at which chemical oxidation processes stop and reduction processes begin, due to oxygen consumption by biological processes.

Reference Area – A Reference Area has similar physical and biological attributes to the experimental area of interest but lies at sufficient distance to avoid the influence of the factors driving changes in the experimental area, most commonly human activities. Reference areas are ideally sampled over long periods of time to take into account seasonal and annual differences in attributes.

Region – A broad geographic area delineated by similar physical and biological attributes that differ from those of adjacent regions. In the context of the protocols framework, the largest spatial scale over which specific data collection efforts could be extrapolated is a region.

Resident Fish – Fish that maintain home ranges or that stay in a relatively stable geographic area throughout most of their life cycles.

Resource Assessment – In the context of ocean energy, a measurement of the total energy contained in the offshore wind, wave or tidal resource for a region or project. This measurement does not provide an assessment of the magnitude of the practical extractable energy for an area.

Resource Inventory – An inventory of the natural resources in a locale or region including biological, physical, chemical and geological resources. Resource inventories are often performed to develop a baseline prior to the onset of human activities, against which future changes can be measured.

Risk Assessment – An evaluation of the potential adverse effects of an action; specifically, the evaluation of ecological risk gained from rigorous assessment of the exposure and effects of stressors on receptors.

Rugosity – A measure of the roughness of a substrate, related to the size and angularity of particles in sediments.

Sampling – Acquisition of environmental monitoring data.

Scale Factor – The appropriate sampling intervals and locations to determine the effects of ocean energy development is dependent on the inherent spatial and temporal scales of the stressors and receptors

Scyphozoan – A jellyfish from the Class Scyphozoa, Phylum Cnidaria.

Sensitivity – In environmental risk assessment, the magnitude of response of a specific receptor to a specific stressor. Sensitive species or other ecological characteristics are targeted for monitoring studies with the rationale that they provide early warning of environmental effects from the stressors of a given human activity.

Side-Scan Sonar – A multibeam acoustic device that actively sends out a sound signal and receives the return to measure depth and backscatter.

Signature – The specific characteristics of a signal; which in this context, include chemical, acoustic, and electromagnetic signals.

Splitbeam – An acoustic instrument that sends out two parallel sound signals and measures their return to identify targets such as fish. This technology acoustically sees objects but cannot distinguish among species.

Stressor – An agent of change in the environment.

Sub-Bottom Profiling – An acoustic methodology using low frequency sound to look through sediment layers to determine their thickness and the underlying strata.

Theodolite – An instrument for measuring precise angles in the vertical and horizontal; they may be used to accurately estimate range and distance of features, such as migrating whales.

Threshold – Scientific thresholds are defined as the minimum intensity or value of a stressor that will produce an effect on a receptor; for example a threshold for harm to a very small marine mammal population might be the loss of one or more reproductive individuals. Regulatory thresholds are those levels at which a stressor affects a receptor, triggering a regulatory or statutory response; for example, the loss of individuals of a population under the Endangered Species Act might trigger a jeopardy finding.

Trigger – In adaptive management, an environmental monitoring measure or value that requires a particular action or response.

Validation – The use of ground-truthing to test estimations or simulations from remotely sensed data or numerical models.