OCS Study
BOEM 2012-082

Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship

National Oceanographic Partnership Program

U.S.Department of the Interior
Bureau of Ocean Energy Management
Office of Renewable Energy Programs
www.boem.gov

OCS Study
BOEM 2012-082

Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship

National Oceanographic Partnership Program

Author:

J. McCann

This study was funded by the Bureau of Ocean Energy Management, Regulation and Enforcement, U.S. Department of the Interior, Washington D.C., under Contract Number M10PC00097
by
The University of Rhode Island
Coastal Resources Center
220 South Ferry Road
Kingston, RI 02881-1967

Published by
U.S. Department of the Interior
Bureau of Ocean Energy Management **Herndon, VA.**
Office of Renewable Energy Programs **September, 2012**

DISCLAIMER

This report was prepared under contract between the Bureau of Ocean Energy Management (BOEM) and The University of Rhode Island. This report has been technically reviewed by BOEM, and it has been approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of BOEM, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. It is, however, exempt from review and compliance with BOEM editorial standards.

REPORT AVAILABILITY

This report is available only in compact disc format from the Bureau of Ocean Energy Management, Herndon, VA. by referencing OCS Study BOEM 2012-082. The report may be downloaded from the boem.gov website through the Environmental Studies Program Information System (ESPIS). You will be able to obtain this report also from the National Technical Information Service in the near future. Here are the addresses. You may also inspect copies at selected Federal Depository Libraries.

U.S. Department of the Interior
Bureau of Ocean Energy Management
Office of Renewable Energy Programs
381Elden Street, HM 1328
Herndon, Virginia 20170
Office (703) 787-1329
Fax (703) 787-1708

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
Phone: (703) 605-6040
Fax: (703) 605-6900
Email: bookstore@ntis.gov

CITATION

J. McCann (2012). *Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship*. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA., OCS Study BOEM 2012-082, 626 pp.

DEVELOPING ENVIRONMENTAL PROTOCOLS AND MODELING TOOLS TO SUPPORT OCEAN RENEWABLE ENERGY AND STEWARDSHIP

TABLE OF CONTENTS

FINAL REPORT

NATIONAL OCEANOGRAPHIC PARTNERSHIP PROGRAM (NOPP)

DEVELOPING ENVIRONMENTAL PROTOCOLS AND MODELING TOOLS TO SUPPORT OCEAN RENEWABLE ENERGY AND STEWARDSHIP

SEPTEMBER 21, 2010 – SEPTEMBER 20, 2012

PROJECT NUMBER: M10PC00097

Submitted By:

Jennifer McCann
University of Rhode Island
Kingston, Rhode Island 02881

Project Management Team:

Jennifer McCann, URI Coastal Resources Center
Dr. John King, URI Graduate School of Oceanography
Dr. Malcolm Spaulding, URI Department of Ocean Engineering
Grover Fugate, Rhode Island Coastal Resources Management Council
Dr. Deborah French McCay, RPS ASA

Contributing Authors:

Michelle Carnevale, URI Coastal Resources Center
Chris Damon, URI Environmental Data Center
Eileen Graham, RPS ASA
Dr. John Jensen, Sea Education Association
Dr. Robert Kenney, URI Graduate School of Oceanography
Dr. Rod Mather, University of Rhode Island, Department of History
Dr. Peter Paton, URI College of Environmental and Life Sciences
Danielle Reich, RPS ASA
Melanie Schroeder, RPS ASA
Dr. Malia Schwartz, URI Graduate School of Oceanography
Dr. Emily Shumchenia, URI Graduate School of Oceanography
Dr. Sarah Smith, URI Coastal Resources Center
Kristopher Winiarski, URI College of Environmental and Life Sciences

This study was funded by the Bureau of Ocean Energy Management, Regulation and Enforcement, U.S. Department of the Interior, Washington, D.C., under Contract Number M10PC00097.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This document serves as the Final Report (Draft) for National Oceanographic Partnership Program project number M10PC00097, *Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship.* This document presents a summary of the findings of this project, and summarizes each of the individual reports completed as part of this project.

Offshore renewable energy (ORE) development is the construction and operation of one or more devices designed to harness power from the marine environment (wind, tidal, and wave power considered here), and includes any necessary infrastructure, including subsea cables, the vessels necessary to construct or install an ORE development, and the footprint of a project. The motivation for this work was to provide BOEM and the nation with a comprehensive, yet flexible and tested means of making efficient and balanced assessments regarding the impacts of a broad range of ORE projects on marine and human ecosystems. With these tools, BOEM will have the capacity to proactively and comprehensively manage ocean renewable energy resources and implement adaptive management techniques for the benefit of natural and human ecosystems and the nation. The goal of this particular project was to develop and test standardized protocols for baseline studies and monitoring for the collection and comparison of scientifically valid and comparable data for specific ORE issues, which seamlessly integrate with a newly designed conceptual framework and approach for cumulative environmental impact evaluation of ORE development. This goal consists of two objectives, addressed by the following reports:

Objective 1: Develop and test standardized protocols for baseline studies and monitoring for the collection and comparison of scientifically valid and comparable data for specific ORE issues;

1. Task 1.2: Report on Monitoring the Potential Effects of Offshore Renewable Energy
2. Task 1.3: A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction
3. Task 1.4: Standardized Protocols for Assessing the Effects of Offshore Alternative Energy Development on Cultural Resources
4. Task 1.5: Developing Standardized Protocols and Monitoring

Objective 2: Develop a conceptual framework and approach for cumulative environmental impact evaluation of ORE development, as part of a larger framework for a site evaluation tool for decision makers;

1. Task 2.3: Report on the Framework for Cumulative Impact Evaluation

The timeline of completion for these Tasks followed a logical progression from understanding the basic environmental concerns related to ORE developments (Task 1.2), to evaluating current monitoring standards (Task 1.3), to developing new U.S. standards for monitoring ecological and cultural resources (Task 1.4 and Task 1.5, respectively), and finally, to developing a site evaluation and impact assessment tool (Task 2.3).

The body of work undertaken for this project meets an urgent need to bring consistency to ORE data collection, provide comparability across state and federal ORE projects, and help coastal managers apply these data to make better management decisions and to better understand the cumulative impacts. This effort involved the collaboration and input from scientists, regulators, industry and non-government environmental organizations in the U.S. and Europe.

Summaries of the objectives and the findings of each of these reports follow. For a more complete understanding of each of these products, the reader is encouraged to view the full reports.

2. TASK 1.2: REPORT ON MONITORING THE POTENTIAL EFFECTS OF OFFSHORE RENEWABLE ENERGY

Major findings:

- No potential effects of ORE have been newly identified since the publication of the PEIS in 2007.
- A Renewable Energy Effect Matrix helped identify and compare effects across ecosystem components and ORE development types that merit future monitoring.
- We identified fifty-seven moderate or major potential effects across ecosystem components for ORE developments at multiple scales that should be monitored in the future. We need a selection mechanism for choosing which subset of effects is relevant to a particular development scenario.
- By standardizing the collection of the underlying environmental data, assessment models are much more likely to be accurate representations of the ecosystem and widely applicable to a range of ORE development scenarios.

The specific objectives of Task 1.2 were to:

1. Identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, and birds from offshore wind energy (OWE) or marine hydrokinetic (MHK, including wave and tidal energy) development on the Outer Continental Shelf (OCS) that were not discussed within the Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use of Facilities on the Outer Continental Shelf (PEIS) (MMS 2007).
2. Identify and categorize the level of effect and certainty of each potential effect of OWE and MHK at the following scales: demonstration scale (Scale 1), commercial scale (Scale 2), and multiple facilities within a region (Scale 3).

3. Outline potential effects that require monitoring at future OWE and MHK facilities and for which protocols would be developed under Task 1.5.
4. Discuss how data collected during monitoring can be used to support cumulative impact assessments and associated models.

2.1. Objective 1—Identify Potential Effects

We considered the effects of ORE developments on the benthic habitat and resources, marine mammals, sea turtles, fish, and avian species. We also considered the effect of ORE developments on one human use—fishing activity—because of the inextricability of the effects on fishing activity from effects on fish themselves, and the resulting concerns of fishermen about potential effects on their livelihood. To identify any additional potential effects from offshore wind energy (OWE) or marine hydrokinetic (MHK) developments that were not discussed within the PEIS, we conducted a literature review of studies and reports completed after the 2007 PEIS publication date. In addition, we consulted U.S. resource experts, European researchers, and industry members on the Project Advisory Committee (PAC) for this project to ensure all potential effects were included. After an extensive literature review, we found that, while there have been many new reports, studies, and proceedings on the effects of ORE, no potential effects of OWE or MHK have been newly identified since the publication of the PEIS. Members of the PAC confirmed through multiple meetings and discussions during a year-long process that no additional potential effects have been identified.

2.2. Objective 2—Categorize the Level of Effect and Certainty

Once all potential effects were identified, we categorized each effect according to the predicted level of effect and the level of certainty at each scale of development and for each technology type within the Offshore Renewable Energy Effect Matrix. While the results of the Offshore Renewable Energy Effect Matrix (see Appendix C of the Task 1.2 report) are not meant to be static and should be updated frequently as new information is available, the current findings were used as a guidance tool to identify the potential effects that merit future monitoring. In addition to the matrix, we examined the monitoring requirements established for demonstration MHK and OWE projects currently permitted in the U.S..

We examined ORE developments at three scales, 1 = "demonstration", 2 = "commercial", and 3 = "multiple commercial." At Scale 1, three or fewer devices are part of a "farm;" Scale 2 constitutes a farm of around 100 devices, and Scale 3 constitutes multiple commercial facilities in a region. Potential impacts were categorized by the five affected ecosystem components, the anticipated level of effect (minor, moderate, major), and the level of certainty (high, medium, low) at each scale of development and for each technology type within the Effect Matrix. The descriptions and thresholds for effect levels were derived from the definitions used in the PEIS [18]: minor—should not influence or have only small impacts on the affected resource, activity, or community; moderate—impacts could moderately influence the resource, activity, or community, generally or for particular species; major—impacts could significantly influence the resource, activity, or community, generally or for particular species. Here, we used the word "certainty" to refer to the amount of evidence available from studies conducted on a particular effect. High certainty indicates that there was a large body of literature documenting or studying an impact. It is important to note that "certainty" does not refer to the chance that an impact will occur. The chance of an impact occurring is more appropriately described as likelihood, a concept that was not addressed in this study. Therefore, where we describe an effect with a high certainty of major impact, this can be interpreted as "if the named effect occurs, then the magnitude of the impact on environment will be major."

2.3. Objective 3—Outline Potential Effects That Require Monitoring

To develop a list of potential effects to be monitored, we first considered only moderate or major effects at any scale. The potential release of toxic fluids, chemicals or other debris, as well as the risk of a large spill from a vessel accident was categorized under multiple topic areas as a moderate to major effect, but was shown to have a relatively low likelihood of occurrence. Therefore, it was determined that monitoring for this effect was not necessary. We noted that the implementation of oil-spill response plans could minimize the damage caused by a release of toxic fluids, chemicals, or other debris.

Through a combination of the Renewable Energy Effects Matrix and expert judgment, we created a list of effects for each ecosystem component and at each development scale that warrant future monitoring, or for which we would develop protocols under Task 1.5 (Table 1). It is important to note that it is unlikely that a particular ORE project will involve monitoring for all of the effects listed in Table 1; the Task 1.5 report includes a mechanism for selecting appropriate protocols.

Table 1

Potential effects for which monitoring protocols were developed

Benthic Habitat and Resources	
Scale 1 (Demonstration Scale)	• Scour around device • Changes in median grain size or organic content • Turbidity during construction/decommissioning • Change in target species abundance and distribution (e.g, species of importance) • Colonization density, composition of communities on foundations
Scale 2 (Commercial Scale)	• Changes to seafloor morphology and structure (compared to pre-construction) • Changes in median grain size or organic content • Turbidity during construction/decommissioning • Change in target species abundance and distribution (e.g, species of importance) • Change in density, diversity, dominance structure of infauna • Colonization density, composition of communities on

	foundations • Current speed/direction inside and outside farm
Scale 3 (Multiple Commercial Facilities in a Region)	• Changes to seafloor morphology and structure (compared to pre-construction) • Changes in median grain size or organic content • Change in target species abundance and distribution (e.g., species of importance) • Change in density, diversity, dominance structure of infauna • Hydrodynamics inside and outside farms throughout region
Fish	
Scale 1	• Reef effects • Blade strikes (tidal power)
Scale 2	• Reef effects • Changes to abundance/distribution • Installation noise effects (for devices requiring pile driving) • Operational noise effects • EMF effects • Blade strikes / pressure gradients (tidal power)
Scale 3	• Reef effects • Changes to abundance/distribution and community composition on regional scale • Installation noise effects (for devices requiring pile driving) • Operational noise effects • EMF effects • Blade strikes / pressure gradients (tidal power)
Fisheries	
Scale 1	• Loss of access to grounds
Scale 2	• Catchability during construction • Catchability during operation • Loss of access to grounds • Changes in species distribution • Reef effects (aggregation)
Scale 3	• Catchability during construction • Catchability during operation • Loss of access to grounds • Changes in species distribution • Reef effects (aggregation)

Avian Species	
Scale 1	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Scale 2	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Scale 3	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Marine Mammals and Sea Turtles	
Scale 1	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes
Scale 2	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes
Scale 3	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes • Changes in life history and demographics

2.4. Objective 4—Support for Cumulative Impact Assessments

Cumulative impact assessments and associated models are built on ecological indices or metrics that rely on quantitative data. By standardizing the collection of the underlying data, assessment models are much more likely to be accurate representations of the ecosystem and widely applicable. In this way, standardized protocols for environmental monitoring at ORE developments can support cumulative impact assessments and encourage their development.

3. TASK 1.3: A COMPREHENSIVE REVIEW AND CRITIQUE: EXISTING U.S AND INTERNATIONAL MONITORING PROTOCOLS FOR OFFSHORE RENEWABLE ENERGY DEVELOPMENT AND OTHER MARINE CONSTRUCTION

Major findings:

- The appropriate monitoring protocols for a given project were project- and site-specific, determined by the size of the project and the potential for environmental effects, in turn determined by the location and the species present at the project site.
- Baseline assessments that provide sufficient information to be compared with construction and post-construction monitoring data are critical.
- While many types of monitoring protocols exist and are currently employed, there are no standards for monitoring offshore activities in the U.S., and in Europe, Germany is the only country at the writing of this report that had adopted standards for monitoring ORE developments.

The specific objectives of this task were to:

1. Conduct a comprehensive literature review of all protocols and monitoring requirements in the United States relevant to offshore marine construction and development.
2. Conduct a comprehensive review of the monitoring standards and methodologies used to evaluate the impacts of wind and hydrokinetic projects in Europe.
3. Complete a literature review and critique of other recommended monitoring practices from the scientific literature for each of the topic areas.

3.1. OBJECTIVES 1 AND 2—LITERATURE REVIEW OF MONITORING IN U.S. AND EUROPE

We compiled a summary and comparative evaluation of existing monitoring protocols and practices used to monitor environmental effects of ORE development to benthic habitat and resources, fish and fisheries, marine mammals, sea turtles, and birds. The protocols summarized include those used in ORE projects and other types of marine construction activities, both within the United States and around the world. For any type of monitoring, it is critical to conduct baseline assessments that provide sufficient information to be compared with construction and post-construction monitoring data. These assessments should employ the same methods as later monitoring in order to compare data and detect changes in the resource being studied. It is also important that data are collected post-construction over a sufficient time period to detect effects that may not be immediately apparent. In collecting data for the purposes of monitoring, it is essential to consider both spatial and temporal variation. Many studies conducted to date for assessing environmental effects from ORE projects employ some type of statistical strategy or model (including Before-After-Control-Impact (BACI) design) (DONG Energy 2006; Stokesbury and Harris 2006; Teilmann et al., 2006; Degraer and Brabant 2009; Derweduwen et al., 2010; FERC 2010; Inger et al., 2010; Brandt et al., 2011; van der Wal et al. 2011), which use a control area against which to compare spatial and temporal effects. Some authors within the literature have recommended a Beyond BACI design (MMS 2001; Reedsport OPT Wave Park LLC 2010), which allows for multiple control sites to account for natural spatial variation. There is no agreement in the particular statistical strategy or how many control sites should be used, nor does there appear to be consistency in the amount of data collected, study duration, or sampling time periods.

Overall, we found that, while many types of monitoring protocols exist and are currently employed, there are few standards for monitoring within any of these subject areas. While there is considerably more documentation of OWE projects than MHK projects, because there have been many more OWE projects developed within the last decades, monitoring data for any ORE project are sparse. Within Europe, despite the proliferation of OWE facilities, most monitoring for effects does not follow any recognized standard (OSPAR Commission 2004, 2006, 2008; JNCC, NE & CCW 2010), and there is little consistency in the data collected at each site. Germany was the single exception and has adopted standards for monitoring ORE developments (BSH 2007). Existing monitoring practices are also inconsistent between countries. Within the United States, most other offshore development industries, including the offshore oil and gas industry, do not have standardized protocols for monitoring the effects of these activities (Erich et al., 2006; FERC 2006). There are currently no specified protocols for protected marine species monitoring and mitigation for potentially harmful activities in U.S. waters.

The National Environmental Policy Act (NEPA) applies to all topic areas examined in this project and defines the overall environmental impact assessment process. For marine mammals, two other federal statutes come into play—the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). The MMPA applies to all marine mammals, including cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, sea lions, fur seals, and walrus), sirenians (manatees and dugong), sea and marine otters, and polar bear. The ESA only pertains to species formally classified as Endangered or Threatened under the Act, which can be entire species, subspecies, or smaller populations/stocks/subsets (distinct population segments [DPS] in the statute). At present there are 31 marine mammal species or DPSs listed under the ESA, 24 as Endangered and 7 as Threatened. Although there is a large degree of overlap in the definitions, prohibitions, requirements, and regulations under the ESA and MMPA, there are some differences. There is not a specific federal statute protecting all sea turtles, equivalent to the MMPA, however all sea turtle species or designated populations known to occur in U.S. waters are designated as either Endangered or Threatened under the ESA.

3.2. REVIEW OF MONITORING APPROACHES BY TOPIC AREA

3.2.1. Benthic Habitat and Resources

Overall, it was acknowledged in the literature that natural variation is high in benthic communities, and therefore at least two separate sampling efforts should be undertaken for a pilot or baseline study (Carey and Keough 2002; Walker et al., 2009). For studies of the benthic environment, the same methods are often used for both baseline assessments and the subsequent monitoring, and in most cases, continuity in methodology and instrumentation is essential in order to detect change (OSPAR 2002).Surveys of benthic habitat and resources commonly include combinations of remote sensing and direct sampling tools. Remote sensing is accomplished with geophysical methods and sampling methods utilizes one or more of the following methods: underwater video/photography surveys, grab samples, and beam trawls (e.g., Meibner and Sordyl 2006; Brown and Collier 2008. Optical backscatter sensors or turbidity sensors have been utilized in order to examine water velocity and sediment resuspension above benthic substrates (ABPmer Ltd. et al., 2010; Van den Eynde et al., 2010).

The nature of the field sampling design is a critical consideration for benthic monitoring plans. Estimating or modeling existing variability (e.g., Daan et al. 2009; ESS Group Inc. 2011) will prevent the need for additional samples in order to detect effects (Carey and Keough 2002). Placement of reference stations should, at the very least, attempt to replicate the substrate type of the impact sites, but also be placed in areas with similar hydrodynamics (Jarvis et al., 2004) and other levels of anthropogenic impact (BSH 2007). A consensus among most monitoring programs was that at least three replicate samples should be taken at each sampling station (e.g., Emu Ltd. 2006; BSH 2007; Walker et al., 2009; Ware et al., 2010).

3.2.2. Fisheries Resources and Fishing Activity

There are relatively well-established techniques for monitoring fish distribution and abundance; trawl surveys have been used for many years in both the U.S. and Europe to establish stock assessments (e.g., NMFS, Massachusetts Division of Marine Fisheries, CEFAS 2010). Trawl surveys can be used on a large scale to collect baseline data and to evaluate changes to abundance and distribution of fish around ORE devices. Trawl surveys are best suited to assessing demersal and benthic species; acoustic surveys, which are more appropriate for pelagic species, should be done in conjunction with trawl surveys. For commercially valuable invertebrates such as lobster, a ventless trap survey can be used to assess distribution and abundance (de Lestang et al., 2011).

Noise effects on fish are not well understood (Wahlberg and Westerberg 2005; Popper and Hastings 2009). Surveys of distribution and abundance can be used to assess the effects of operational noise, while acoustic or catch surveys can be used to evaluate the effects of construction noise. The effects of EMF are even less well understood; these have been studied by various catch studies using nets or traps, including mark-recapture studies, and by mesocosm studies (Martec Ltd. 2004; Westerberg and Lagenfelt 2008; Gill et al., 2009). Acoustic monitoring and video monitoring, perhaps in tandem, can be effective for monitoring blade strikes from tidal energy devices; both were used for the Verdant Power tidal energy project (Verdant Power LLC, 2010). Reef effects on turbines have been monitored in a variety of ways, including underwater video on ROVs or by divers, and by acoustic monitoring. With the exception of reef effects, these effects have been little studied, and thus there is no consensus of the best methods by which to monitor them.

Studies of wind farms in Europe have used all of the above-mentioned techniques to study possible effects to fish (e.g., Grift et al., 2003; DONG Energy 2006; BSH 2007; Barrow Offshore Wind Ltd. 2009; Derweduwen et al., 2010), although there is little consistency in which are used, and no consistent protocols about how much data are collected and over what time period. Again, Germany is the exception, requiring at least two years of baseline data, and monitoring every other year for five years during the operational phase, with specifications about the numbers of hauls and the sizes and distances of reference areas (BSH 2007).

There are no standards in place for monitoring fishing activity. Within the U.S., various types of data are collected by NMFS that are often used for monitoring fisheries, but depending on the data set used there can be some limitations in terms of confidentiality requirements for how the data can be displayed, not accounting for activity by vessels without federal fishing permits, or a recording only where fishing trips begin and not complete fishing tracks. Interviews and surveys are sometimes used, and have been used in the U.K. (NWP Offshore Ltd. 2008), to determine changes to fishing activities and perceptions to changes (AMEC 2002).

3.2.3. Marine Mammals and Sea Turtles

Unlike the other topic areas discussed in this document, some of the techniques for monitoring marine mammals are fairly well defined. There is a substantial range of potential impacts on marine mammals and sea turtles from the construction, operation, and decommissioning of ORE installations (see Table 1). Noise impacts comprise the most substantial concerns, however there are other types of impacts that must be considered NRC (2005) included a conceptual model called PCAD (Population Consequences of Acoustic Disturbance) as a guide for a recommended future research program. The Office of Naval Research has more recently funded an extensive PCAD study (PCAD Working Group 2010) with the objective of expanding the NRC conceptual model into something much more quantitative. The PCAD project intends to develop elaborate Bayesian population models for selected marine mammal species with extensive long-term datasets, which would allow prediction of effects on their demography and life history from acoustic or other disturbance. The species under study include elephant seals, coastal bottlenose dolphins, and North Atlantic right whales (in that order). The first papers on the elephant seal model are currently in review (J. Clark, Duke Univ., pers. comm.).

Baseline assessments and post-construction monitoring of both marine mammals and sea turtles can be conducted using vessel-based surveys and aerial surveys. Passive acoustic monitoring (PAM) can be used for marine mammals to detect individual animals within a given area, but the devices are expensive and presently are only able to definitively identify a few species. PAM sensors can be towed behind a vessel conducting shipboard visual surveys as a means of ground-truthing and supplementing the visual data. Focused studies utilizing photo-identification and tagging are very likely to detect effects from ORE on individual animals.

During pre-construction seismic surveying and pile-driving activity in the construction phase, the Cape Wind project is required to have a monitoring zone with a NMFS-approved observer who will observe whether marine mammals and sea turtles come within a certain distance of the activity, requiring operations to be shut down until the animal leaves the vicinity. This serves as both a monitoring and mitigation measure, and similar measures are likely to be required for other ORE projects permitted within the United States.

3.2.4. Avian Species

Ornithologists have developed a number of survey techniques to assess the potential impact of ORE development on avian populations in offshore areas. The primary methods used to quantify changes in the spatial distribution and abundance of birds over a variety of spatial scales are ship-based and aerial surveys (Camphuysen et al., 2004). Ship-based surveys allow for a fine level of detail, but can be expensive and slow, requiring more time to cover a large geographical area. Aerial surveys allow for more coverage of a larger geographic area in a shorter period of time, but do not always allow for identification to the species level, can cause disturbance, and may underestimate bird numbers. High-definition video surveys are also now being used along with more traditional visual surveys. Radar studies can be used to assess distribution and abundance of birds at a potential ORE development. Radar may also be useful in assessing collisions with the turbine. Acoustic survey is another methodology that could be used to detect birds at night, particularly to assess collision risk; there is little experience with this technology in the offshore environment. Infrared cameras are another technology that has been used in Europe to assess collision risk, although this method may not be cost effective.

A robust BACI monitoring survey design is crucial to detect static avian effects such as displacement or attraction due to the physical structure of ORE devices. The ability to detect displacement or attraction (i.e., statistical power) is based on sample size for a given avian group or species, variability with those samples, and the degree of the effect (displacement or attraction; see Inger et al., 2010).

Monitoring standards in Germany call for two years of baseline data, and at least three, preferably five, years of post-construction monitoring (BSH 2007). The standards require both ship-based and aerial surveys to monitor distribution and abundance. Likewise, monitoring at wind farms in the U.K. has employed both ship-based and aerial monitoring with varying levels of each. (see Maclean et al., 2009)

4. TASK 1.4: STANDARDIZED PROTOCOLS FOR ASSESSING THE EFFECTS OF OFFSHORE ALTERNATIVE ENERGY DEVELOPMENT ON CULTURAL RESOURCES

Major findings:

- Geophysical survey standards for archaeological resources should include two Tiers. Tier 1 should be composed of broad baseline surveys and Tier 2 should follow BOEM's proposed standards for full-scale archaeological surveys except for requiring either (1) side scan sonar and multibeam surveys or (2) interferometric sonar surveys.
- A Cultural Landscape Approach is recommended to better integrate human factors in marine resource management, and incorporates research

and management methods that are sensitive to and inclusive of tribal and indigenous people and working maritime communities.

- Archaeological Sensitivity Analysis was used in Rhode Island waters to better explain historic shipwreck distributions and showed great potential as a tool for ORE baseline studies by identifying areas with greater likelihood for containing cultural resources and helping developers and managers assess project time, costs, and threats to cultural resources.

The specific objective of this task were to:

1. Develop standards for geophysical survey in anticipation of ORE development.
2. Develop a conceptual framework for incorporating a Cultural Landscape Approach (CLA) for assessing and understanding cultural resources in areas that have been identified for potential ORE development.
3. Develop the use of Archaeological Sensitivity Analysis (ASA) to evaluate and assess cultural resources in potential ORE lease blocks.

This Task, to develop standardized protocols for assessing the effects of ORE facility construction, operation and decommissioning on cultural resources, was conducted in parallel to Tasks 1.2 and 1.3 focusing on ecological resources.

We outlined a two-tier approach to geophysical survey, instrumentation and survey resolution for Objective 1. "Tier 1" was defined as broad baseline surveys that are appropriate for evaluating the likely general effects of ORE development in any particular area. For Tier 1 surveys, contains recommended strategies and instrumentation that are commensurate with these objectives. Tier 2 surveys are more detailed and correspond with archaeological surveys required by BOEM prior to development, disturbance and installation. For Tier 2 surveys, we recommended slight modifications in current BOEM guidelines and standards for archaeological surveys.

In order to identify and evaluate the potential effects of ORE siting on marine cultural heritage resources, we outlined a CLA in Objective 2. Pioneered and partially implemented in the Rhode Island Ocean Special Area Management Plan (SAMP), CLA advances the integrated management of cultural and environmental resources with the goal of improving the performance of NEPA and Section 106 reviews under the National Historic Preservation Act (NHPA) and to bring them into better alignment with the National Ocean Policy and its nine priority areas. We recommend the adoption of new definitions and categories for cultural heritage resources developed under the auspices of the National Marine Protected Area Federal Advisory Committee in 2010. While specific protocols for including tribal and indigenous cultural heritage were not provided here, we strongly recommend the need for early and meaningful consultation with these groups as well as members of working maritime communities in developing landscape contexts and preservation priorities. CLA, offers a multidisciplinary and multicultural approach to cultural heritage that operates along the full spectrum of geographic scales, from the local to the global.

For Objective 3, we evaluated three types of models and associated techniques that have the potential to contribute to assessing the effects of ORE development on submerged cultural resources. These are Predictive Modeling, Paleo-Archaeological Landscape Reconstruction, and ASA. While statistical predictive models appear to be prohibitively time consuming and expensive, irrespective of whether they are designed for prehistoric or historic sites, both preliminary Paleo-Archaeological Landscape Reconstruction and ASA hold considerable potential. Using the SAMP as a case study, we looked at ways to enhance ASA for historic sites, particularly shipwreck locations, using readily available data and linear regression. While the patterns of shipwreck loss revealed by the analysis of Rhode Island data may not be applicable in every location, the methodology for revealing those patterns is likely to be broadly pertinent.

4.1. Objective 1—Standards for Geophysical Survey

Broad reconnaissance-type archaeological surveys are appropriate for baseline studies in anticipation of ORE development. We recommend, therefore, a two-tier approach. "Tier 1" would be archaeological surveys as part of broad baseline studies. "Tier 2" would be archaeological surveys of Areas of Potential Effect (APE) from offshore development (APE is the term used by BOEM and is common in cultural resource management). Tier 2 surveys are, in essence, similar to those already required by BOEM. Certainly, standards and instrumentation for these two tiers of survey could and should work in tandem, but in both conceptual and practical terms they would have to be separated to some degree.

We propose that Tier 1 studies dovetail with more intensive Tier 2 studies, but that the structure, instrumentation, and perhaps survey design (e.g., acoustic transect lane spacing) be somewhat different. In the first instance, most ORE projects establish general areas for development, rather than specific locations for OWE or MHK installations (sources). It is for this reason that broad, reconnaissance-level studies are recommended. Reconnaissance-level survey will not mitigate the needs for detailed cultural resource assessments should an Environmental Impact Statement be required (i.e., Tier 2 surveys), but it will establish good baseline data about potential sites and areas of archaeological sensitivity. This in turn will help inform both CLA and ASA.

We propose that Tier 2 studies parallel current and proposed BOEM standards for full-scale archaeological survey, with one principal exception. We recommend that the agency restructure its acoustic mapping studies so as to incorporate multibeam technology more fully. Currently, BOEM requires side-scan sonar surveys, single-beam echo-sounder surveys, and encourages multibeam surveys (BOEMRE, n.d.). We propose that the agency require either (1) side-scan sonar and multibeam bathymetry surveys or (2) interferometric sonar surveys.

4.2. Objective 2—Cultural Landscape Approach

The CLA to maritime cultural heritage resources addresses contemporary management challenges by providing an open-ended and rigorous framework that integrates data and perspectives from the physical and social sciences, humanities, and traditional/place-based knowledge systems. CLA recognizes that places and cultural heritage resources can have different or multiple meanings and levels of significance based on how people from different cultures, times, or backgrounds have interacted with the landscape. Adopting this pluralistic approach increases the likelihood that cultural heritage resources will be found, recognized, and appropriately respected as decisions are made about the siting and potential effects of ORE projects.

CLA offers fundamental principles about the nature of cultural heritage resources and suggests methods for identifying and characterizing interactions between human cultures and activities and coastal and marine environments. Cultural heritage resources, whether in the form of archaeological sites or living cultural practices, are records of these interactions over time. They reveal how people have used and shaped marine environments, and how these environments have shaped human cultural and history. Understanding these interactions may offer our best hope for sustainably and equitably using, maintaining, and where required restoring coastal and marine ecosystems (Crowder and Norse 2008; Douvre 2008).

Support for CLA comes from research completed through the Rhode Island SAMP, the experience of the Cape Wind project in Massachusetts, extensive work by the NOAA National Marine Protected Area Federal Advisory Committee's cultural heritage resources working group, and discussions at the Atlantic Wind Energy Workshop sponsored by BOEM and held on July 12-14, 2011. Using CLA requires better integration of human factors in marine resource management, and incorporates research and management methods that are sensitive to and inclusive of tribal and indigenous people and working maritime communities (Douvre 2008; Pomeroy and Douvre 2008; Crowder and Norse 2008; St. Martin and Hall-Arbor 2008; Elher 2008).

4.3. Objective 3—Archaeological Sensitivity Analysis and Predictive Modeling

We recommend a paleo-archaeological landscape reconstruction as a practical approach for predicting the location pre-contact sites underwater. Such an undertaking could identify areas of pre-contact archaeological sensitivity, and when combined with an enhanced version of ASA for historic sites has great potential as a tool for assessing the impacts of ORE development.

A preliminary paleo-archaeological reconstruction is achievable as part of baseline alternative energy studies. It requires, however, substantial integration of disciplines and methodologies. Using a combination of geological knowledge, sub-bottom data, side-scan sonar data, and coring, it is possible to partially reconstruct the landscape prior to inundation and marine sedimentation. As a result it is possible to identify: areas that were sub-aerially exposed, relic surfaces, glacial lakes, relic riverbeds, and the sedimentary regime. While this, by itself, falls short of a predictive model, it does identify areas that could contain archaeological material and, therefore, have greater archaeological sensitivity.

One important issue is the extent of coring required for paleo-archaeological landscape reconstruction. This requirement can only be determined on a case-by-case basis, but a logical path would to be to determine overall project coring requirements with input from archaeologists, geologists, and physical oceanographers and to use the data in an integrated, interdisciplinary manner. Certainly knowledge about the existence of human populations in areas that were sub-aerially exposed should be one of the driving factors in any coring decision-making process.

ASA holds great potential as a tool for ORE baseline studies for submerged cultural resources. It can identify areas with greater likelihood for containing archaeological resources and can help developers and managers with assessment of time, costs, and threats to cultural resources. A GIS-based ASA could also dovetail well with the results of paleo-archaeological landscape reconstruction. The question remains, however, to what extent can ASA for historic cultural resources, like shipwrecks, be expanded or enhanced so as to add rigor to the process. In an attempt to do this, we used data from the Ocean SAMP to refine and test ASA so as to better explain historic shipwreck distributions in Rhode Island waters.

5. TASK 1.5: DEVELOPING STANDARDIZED PROTOCOLS AND MONITORING

Major findings:

- We propose an adaptive monitoring framework based on indicators of the likely changes to the marine ecosystem due to ORE development. We developed decision trees to identify suites of effects at three development scales depending on energy, structure and foundation type in order to help managers and regulators choose appropriate monitoring protocols for specific ORE projects.
- In total, 31 monitoring protocols were developed, with each tied to one or more indicators of a potential effect.
- Our targeted monitoring protocols inform ORE siting and impact evaluation models by standardizing the collection of data to support and validate such models. The framework and protocols that we developed helped construct lists of monitoring objectives for two case studies in Rhode Island based on nation and local environmental concerns and regulatory objectives.

The specific objectives of Task 1.5 were to:

1. Present the standardized protocols and monitoring systems, specifically to address effects on benthic resources and habitat, fisheries resources, fishing activity, marine mammals and sea turtles, and marine birds, that have been developed using the best scientific methodologies and approaches to ensure valid data collection;
2. Describe clear methods and metrics that are flexible, adaptive, and applicable to a wide variety of sites, environmental conditions, and technologies;
3. Present lessons learned from testing these protocols and monitoring systems on results of the Rhode Island SAMP monitoring and

evaluation initiative, the Technology Development Index (TDI) and the Ecological Value Index (EVI) and Cumulative Impact Models.

Based on the results of the review of potential environment effects due to ORE development (Task 1.2) and the review of existing monitoring protocols (Task 1.3), we identified a need for an overall monitoring framework and standardized monitoring protocols that can be applied to various types of ORE projects throughout the United States. A monitoring framework and standardized protocols would represent a major step toward streamlining the regulatory process of permitting ORE projects. Establishing a set of standardized monitoring protocols is important for developing a broader understanding of the effects of ORE development on various components of the marine ecosystem. These protocols will also assist in answering regulatory questions about siting and scale by providing more data and reducing uncertainty in decision-making.

The framework and protocols that we developed will serve as a guide to both developers and regulators to facilitate the process of determining the most appropriate monitoring protocols for a given ORE project and technology type. These protocols are designed to answer existing regulatory questions about the potential effects of ORE on environmental resources, and about the most appropriate way to monitor these effects. The suite of protocols is intended as a menu of options for data collection from new ORE projects, not as a to-do list for developers. Our findings are not intended to supplant existing federal or state authority to determine what studies should be conducted or what monitoring should be required in order to issue a permit for any form of ORE development.

5.1. Objective 1—Development of Monitoring Protocols

The monitoring protocols we developed are based on our assessment of likely potential effects on environmental resources (see Table 1 and Task 1.2 report). We proposed a suite of indicators for the potential environmental effects of ORE development in order to better direct the monitoring process (Table 2). Specific thresholds for each of these indicators

Table 2

Monitoring Objectives and Indicators

Topic Area	Effect/Monitoring Objective	Indicator
Benthic Habitat and Resources	• Changes to seafloor morphology and structure (compared to pre-construction)	• Increase or decrease in seabed volume
	• Changes in median grain size, or organic content	• Deposition: decrease in median grain size; increase in organic content; increase in seabed volume • Scour: increase in median grain size; decrease in organic content; decrease in seabed volume
	• Turbidity during construction/decommissioning	• Change in water column turbidity

	• Change in target species abundance and distribution (e.g, species of importance)	• Change in abundance, diversity, % cover, multivariate community composition
	• Current speed/direction inside and outside farm	• Change in residual flow rates
	• Reef effects; colonization on foundations	• Increase in % cover, biomass of epifaunal organisms; increase in presence of non-native species;
	• Change in density, diversity, dominance structure of infauna	• Change in abundance, diversity, % cover, multivariate community composition
Fish	• Reef or aggregation effects	• Increase in fish abundance around devices; shift in species composition; increase in presence of non-native species
	• Changes to abundance/distribution caused by disturbance or habitat alteration	• Increase or decrease in fish abundance; increase or decrease in target species; shift in species composition; change in density, diversity, and dominance structure of fish species; increase in presence of non-native species
	• Blade strikes / pressure gradients (tidal power)	• Observation of blade-strike incidents
	• EMF effects	• Not feasible to monitor directly; changes in fish abundance, behavior, or species composition are indicators
	• Installation or Operational noise effects	• Not feasible to monitor directly; changes in fish abundance, behavior, or species composition are indicators

Topic Area	Effect/Monitoring Objective	Indicator
Fisheries	• Catchability (catch per unit effort) during construction	• Catch per unit effort increases or decreases for target species
	• Catchability (catch per unit effort) during operation	• Catch per unit effort increases or decreases for target species
	• Loss of access to grounds	• Changes in numbers of vessels fishing near or withinthe renewable energy area; change in the presence of fixed fishing gear withinor around a renewable energy installation
	• Changes in species distribution	• Shift in species composition; increase in presence of non-native species
	• Reef effects (aggregation)	• Increase in fish abundance around devices; shift in species composition; increase in

		presence of non-native species
Avian Species	• Displacement/ attraction	• Changes in distribution, abundance, or behavior
	• Barrier effects – effects on foraging, roosting, migratory movements	• Animals alter migration or commuting flight paths
	• Collision mortality	• Birds documented striking infrastructure resulting in death or injury
Marine Mammals and Sea Turtles	• Vessel strikes	• Detection of dead or injured animals
	• Noise generated during construction	• Detection of dead or injured animals; changes in distribution, abundance, or behavior
	• Disturbance or injury during all stages of development, including from vessels	• Detection of dead or injured animals; changes in distribution, abundance, or behavior
	• Noise generated during operation	• Changes in distribution, abundance, or behavior

In order to ensure that each component and the unique issues within each component were given adequate attention in any monitoring strategy, we implemented a hierarchical decision-tree framework. While not required in the original contract, we felt that this decision-tree framework would facilitate, for regulators and developers, the process of selecting an appropriate monitoring program. Regulatory members of the PAC, including the U.S. Army Corps of Engineers and the Rhode Island Coastal Resources Management Council, agreed that the decision trees would facilitate this process. Decision trees, as decision-support tools, are easy to follow and can help users evaluate alternatives and the impact of development preferences. Importantly, we recommend the use of these decision trees only after a formal marine spatial planning or scoping process has taken place (i.e., conflicting uses among other marine sectors have been resolved). For this objective, we developed two types of decision trees. The first decision tree—the "Effects Decision Tree"— determines the approximate magnitude of effects from ORED on each ecosystem component considering three factors—energy type, foundation type, and development scale. The second type—"Component Decision Trees"— is a suite of finer-scale decision trees for each of the ecosystem components that determine which monitoring protocols are recommended given a more specific suite of characteristics related to the development type (e.g., stage of development). The Effects Decision Tree takes 39 possible scenarios that result from various combinations of the three development factors and reduces these to six main Effect Scenarios (E1 – E6). Once the user has determined which ecosystem components and associated impacts are of concern for the development under examination, they use the Component Decision Trees to find appropriate protocols. The Component Decision Trees take these component-specific concerns into consideration and terminate with a manageable number of recommended monitoring protocols. For example, the Component Decision Tree for Benthic Habitat and Resources describes 24 total monitoring scenarios, but condenses them into a maximum of four monitoring protocols. Each Component Decision Tree points the user to a series of protocol names and numbers; these are the protocols that should be selected for monitoring given the particular technology type

All demonstration-scale projects fell into a single Effects Scenario (E1) and were considered somewhat differently in the capacity for what monitoring should be required. Demonstration-scale projects are not expected to result in environmental impacts of the same magnitudes as commercial projects for any of the renewable energy device types. However, monitoring protocols implemented at the demonstration-scale will be cheaper due to the smaller spatial footprint of these developments, perhaps enabling a wider variety of protocols to be tested. Demonstration-scale projects provide an opportunity for research to reduce some of the existing uncertainty around the potential environmental effects of ORE projects, assisting regulators in prioritizing monitoring needs and making better decisions. Greater monitoring effort at these early stages may later reduce monitoring requirements at commercial-scale facilities, as impacts are better understood. We recommend that the monitoring requirements for demonstration-scale projects be adaptive.

Our review of the current state of knowledge regarding the effects of ORED and consultation with topic area experts has provided a solid starting point for developing indicators of these effects. Through this effort, we have identified the major ecological components that are highly likely to be affected as OREDs become more widespread. However, there are a few points of weakness in the general understanding of the effects of ORED that could greatly change monitoring needs and/or requirements. First, the impacts of indirect effects (e.g., alteration to food webs) and wholly unanticipated effects are unknown. Data regarding these points may only become available at a later stage of ORED maturity, but current monitoring protocols and regulations should be prepared in anticipation of these types of effects. Next is the current understanding of linkages between effects and indicators. We have recommended that certain environmental/biological parameters be measured, but in many cases we have no estimate of thresholds of concern for these parameters (e.g., how much of a reduction can occur in a bird population before mitigation needs to take place?). The beginning stages of ORED will help clarify the assumptions made between effects and indicators. We recommend that indicators be revised if data supports any changes. A related issue is one of detecting environmental/biological changes due to ORED. In rare cases where the natural variability of a parameter has already been characterized, statistical tools may be used to determine appropriate thresholds or even the sampling protocols themselves (e.g., power analyses; Lapena et al. 2010, 2011a, 2011b). In most cases, however, very little is known about natural variability and our protocols will be measuring it with the comingled effects of ORED. Establishing baselines and/or reference conditions will be particularly important here, along with a solid conceptual framework for monitoring.

To address these needs we recommend that monitoring protocols be implemented with an adaptive and reactive framework in mind (Figure 1). Currently, we have the ability to characterize a baseline condition and assign "reference directions" to indicators (Samhouri et al., 2011), e.g., increases in sediment grain size at every turbine should accelerate monitoring for scour. Reference directions are useful when data are insufficient to establish more quantitative reference levels, but they only provide an indication of a trend, and do not specify when a threshold of irreversible harm has been reached (Samhouri et al., 2011). In an adaptive monitoring framework, data is synthesized to produce more quantitative metrics and thresholds for environment indicators of ORED effects. In a reactive monitoring framework, evidence of an effect should be used to accelerate study of that effect, perhaps by multiple methodologies (refer to Figure 1). Suites of ORED effects indicators would not only provide a clearer path for goal-setting for developers, but would encourage regulatory monitoring protocols to contribute to our general understanding of the natural variation of marine ecosystems and how human activities can be integrated and harmonized.

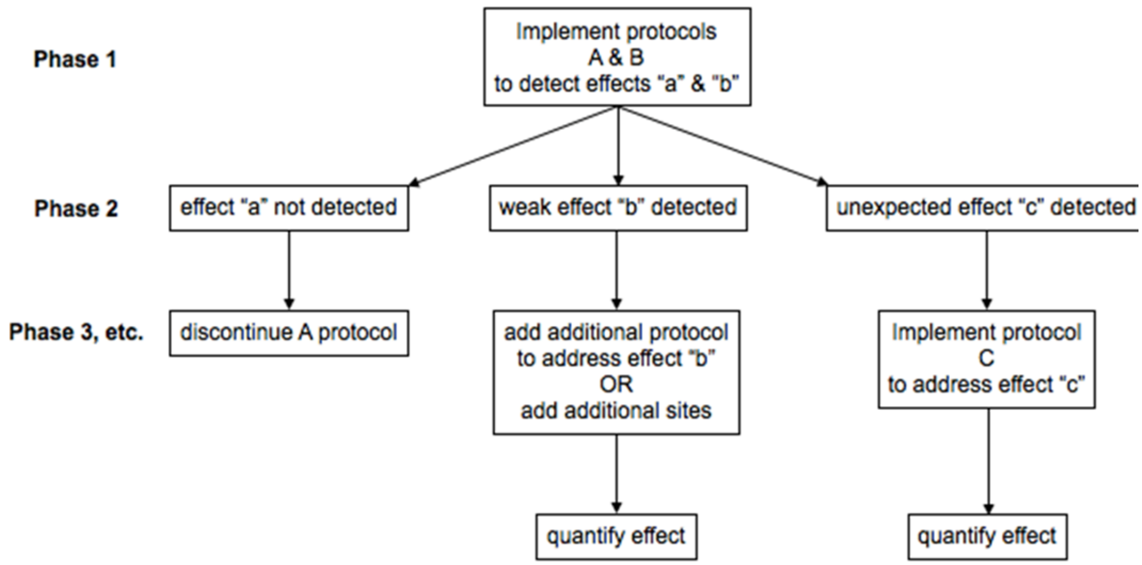


Figure 1. Example adaptive and reactive monitoring framework.

5.2. Objective 2—Describe Methods and Metrics

In total, 31 monitoring protocols were developed, which include twelve to monitor avian species, nine to monitor marine mammals and sea turtles, six to monitor fish or fishing activity, and four to monitor the benthic habitat and resources (Table 3). Each of these protocols is tied to one or more indicators of a potential effect. The intent is not for regulators or developers to use all of these protocols, but to use the decision trees and the protocols to determine the best practices for monitoring effects deemed of concern for a particular project or region. Additionally, several Impact Scenarios were developed to summarize the suite of potential effects that may result from different ORE technology types and to highlight which of those effects are considered to be major or moderate at the scale of a commercial wind farm. These scenarios are intended to assist regulators or developers in determining which effects will be most critical to monitor.

Table 3

Monitoring Protocols Developed in Task 1.5

Benthic Resources and Habitat
W1. Scour and/or deposition
W2. Changes in benthic community composition
W3. Increase in hard bottom habitat
W4. Changes in hydrodynamics
Fisheries Resources and Fishing Activity
X1a. Trawl surveys
X1b. Ventless trap surveys

X2. Monitoring for project-scale changes
X3. Reef and aggregation effects
X4. Blade strikes
X5. Spatial use of fishing activity
Avian Species
Y1. Ship-based visual surveys
Y2. Aerial surveys using human observers
Y3. Aerial surveys using high definition videography
Y4. Aerial surveys using digital still photography
Y5. Radar surveys
Y6. Visual surveys of flight ecology
Y7. Flight call surveys
Y8. Systems to remotely assess collision risk
Y9. Sonar and video technology
Y10. Using radio telemetry to assess movements
Y11. Using satellite telemetry to assess movements
Y12. Using GPS tracking to assess movements
Marine Mammals and Sea Turtles
Z1. Visual surveys
Z2. Passive acoustic monitoring
Z3. Marine mammal observers
Z4. Stranding response networks
Z5. Tagging
Z6. Underwater photography
Z7. SCUBA surveys
Z8. ROV surveys

These protocols were developed with the assumption that there are no or insufficient existing baseline data prior to monitoring. However, in some cases baseline data will exist that can and should be incorporated into monitoring efforts. One example of a case where some baseline data are likely to exist may be species federally listed as Threatened or Endangered under the Endangered Species Act of 1973 and/or protected under the Marine Mammal Protection Act (MMPA). In many cases these species are already being monitored as part of a recovery plan, and their population levels may be better understood. Commercial and recreational fisheries under federal or state management are another resource for which baseline data are likely to exist, as surveys are made on a regular basis to provide stock assessments. However, these data for the most part are conducted over a large spatial scale to provide stock- or species-wide assessments, and may not be useful for monitoring changes on a smaller scale.

5.3 Objective 3—Applying the Protocols and Decision Trees

The project team was also tasked with testing the protocols by applying them to the SAMP, and considering how the additional data collected through these monitoring protocols might affect site-evaluation tools developed by the project team including the Technology Development Index (TDI) and the Ecological Valuation Index (EVI) and Cumulative Impact

Model-Ecological (CIM-Eco). The protocols did not result in any changes to the TDI or EVI/CIM-Eco. However, having standardized methods for collecting baseline and impact data across projects will allow the data to be compiled more easily and incorporated into these models. While baseline data collected for a particular project will likely only cover a project site, adding this information to the model framework may inform future siting. For example, if monitoring studies conducted at demonstration-scale projects indicate that EMF impacts are negligible, the CIM-Eco score can be adjusted to reduce the weighting of EMF impacts in the analysis.

Two case studies are presented, testing the decision tree framework and monitoring protocols for the Block Island Wind Farm in state waters and the Massachusetts and Rhode Island Wind Energy Area in federal waters, both located within the Rhode Island SAMP study area. The test cases found that the framework was successful in selecting a range of appropriate protocols to test potential effects for these two examples. Some knowledge of the local environment including the target species for testing is helpful in choosing monitoring protocols. For the demonstration-scale test case in particular, the list of monitoring protocols provided is longer than the number that would likely be conducted; however, it provides regulators and decision makers with a starting point that is based on the best available science.

6. TASK 2.3 FRAMEWORK FOR CUMULATIVE IMPACT EVALUATION

Major findings:

- We developed a model whereby geospatial information describing the physical environment, ecosystems, and fish and wildlife populations can be integrated into a composite map of ecological value, with weighting factors that incorporate relative intrinsic and ecological values.
- The siting evaluation model (SEM) is composed of two individual models—the CUEM and the TDI which represent ecological and human uses of the environment, along with an indicator of the development "value" of a given location based on the technical challenge of development and the power production potential.
- We integrated data on the benthic and pelagic ecosystems, fish and large invertebrates, birds, sea turtles, marine mammals, and bats.
- Weighting factors acknowledged proportional importance to regional-global scale, resource and protection status, ecosystem component productivity and data robustness.
- The most important factors influencing the results of the Cumulative Impact ecological model are: (1) defining the appropriate scale for the valuation effort; (2) a lack of standardized input data; and (3) patchy or inconsistent data availability/coverage necessitating application of interpolation models or spreading algorithms with uncertain underlying assumptions.

The specific objectives of Task 2.3 were to:

1. Develop methods to design and test a new conceptual framework and approach for a cumulative environmental impact evaluation of ORE development;
2. Outline an overall Siting Evaluation Model (SEM) that considers both ecological values and socio-economic (human) uses;
3. Integrate various ecological data inputs into an Ecological Value Model (EVM) considering multiple levels of organization, i.e., first into ecological components (e.g., individual species) and then ecological categories (e.g., birds, fish, benthic ecosystem);
4. Develop methods to quantify weighting factors and uncertainties for compositing ecological categories into an Ecological Value Index (EVI);
5. Develop methods to quantify weighting factors and uncertainties for modifying the ecological category weights in the EVI related to potential impacts of development in order to generate a Cumulative Impact Model (CIM-Eco), which would become part of the framework for the overall SEM.

The SEM framework developed in this study provides a useful screening tool for initial ORE facility siting considerations, and we intend for it to be used and evaluated in conjunction with other environmental information, regulatory and management priorities, and stakeholder interests. The SEM framework allows for the evaluation of the cumulative impacts of multiple offshore developments and other marine uses.

6.1 Objective 1—Develop Methods and Test a New Conceptual Framework

The approach for this project was to develop a model whereby input data (geospatial information describing the physical environment, ecosystems, and fish and wildlife populations) could be integrated into a composite map of ecological value, with weighting factors that incorporate relative intrinsic and ecological values. The definition of "ecological value" is based on that used in other recent marine spatial planning valuation efforts, such as an on-going European effort (Derous et al., 2007a, 2007b, 2007c), i.e., the intrinsic value of biodiversity without reference to anthropogenic use. At the species level, the input data are based on measures of aggregation: density, contribution to fitness, productivity, rarity, or uniqueness of attributes. Different criteria, such as the regional/global importance of local species, can change the relative importance of the input layers to the model. Going a step further than Derous et al.'s (2007a, 2007b, 2007c) approach, we also applied additional weighting factors to address the relative potential impacts of ORE development using the Offshore Renewable Energy Effects Matrix (Task 1.2), as well as the Impact Decision Tree (Task 1.5).

Categories currently considered in the framework include the benthic ecosystem, the pelagic ecosystem, fish and large invertebrates, birds, sea turtles, marine mammals, and bats. The ecological value model for marine biological resources was tested with an application to the area being considered in the Rhode Island SAMP. A similar framework was described for addressing human uses of marine resources. A model calculation tool (the CIM-Eco Calculator) was supplied as an associated deliverable with the Task 2.3 Report. Using this tool, other weighting schemes may be discussed and evaluated as issues and concerns arise. One of the strengths of the model approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented.

6.2 Objective 2—Outline an Overall Siting Evaluation Model (SEM)

In siting an ORE facility, it is important to consider both ecological and technical feasibility. Therefore, the SEM is composed of two individual models—the Cumulative Use Evaluation Model (CUEM) and the Technology Development Index (TDI).

The CUEM is a combination of the CIM-Eco and a parallel Cumulative Impact Model-Human Use (CIM-HU), which addresses the impacts of development on human uses of the marine environment. The Human Use Index (HUI), parallel to the EVI within CIM-Eco, would be based on relative weighting of socioeconomic categories, which are in turn comprised of components based on data layers. Implementation of CIM-HU was not included in the scope of Task 2.3. The CUEM, as a combination of CIM-Eco and CIM-HU, help a decision maker evaluate the impacts of an offshore development. Ideally, the topology of the CUEM composite index would identify areas most suitable for facility siting (from an ecological and human use perspective) and help inform the analysis of alternatives pursuant to the National Environmental Policy Act. However, because other factors (such as technical feasibility and costs) are also important considerations in the siting of an ORE facility, the CUEM framework and approach is designed to be part of a larger siting-evaluation framework for decision-makers, referred to as the SEM.

The Technological Development Index (TDI) developed by Spaulding et al. (2010) ,is a ratio of the Technical Challenge Index (TCI) to the Power Production Potential (PPP) of the energy extraction device. TCI is a measure of how difficult it is to site the device at a given location plus a measure of the distance to the closest electrical grid connection point. The PPP is an estimate of the annual power production of one of the devices. The site with the lowest TDI represents the optimum. The method can be applied to any ORE type or extraction system once the technical attributes are specified.

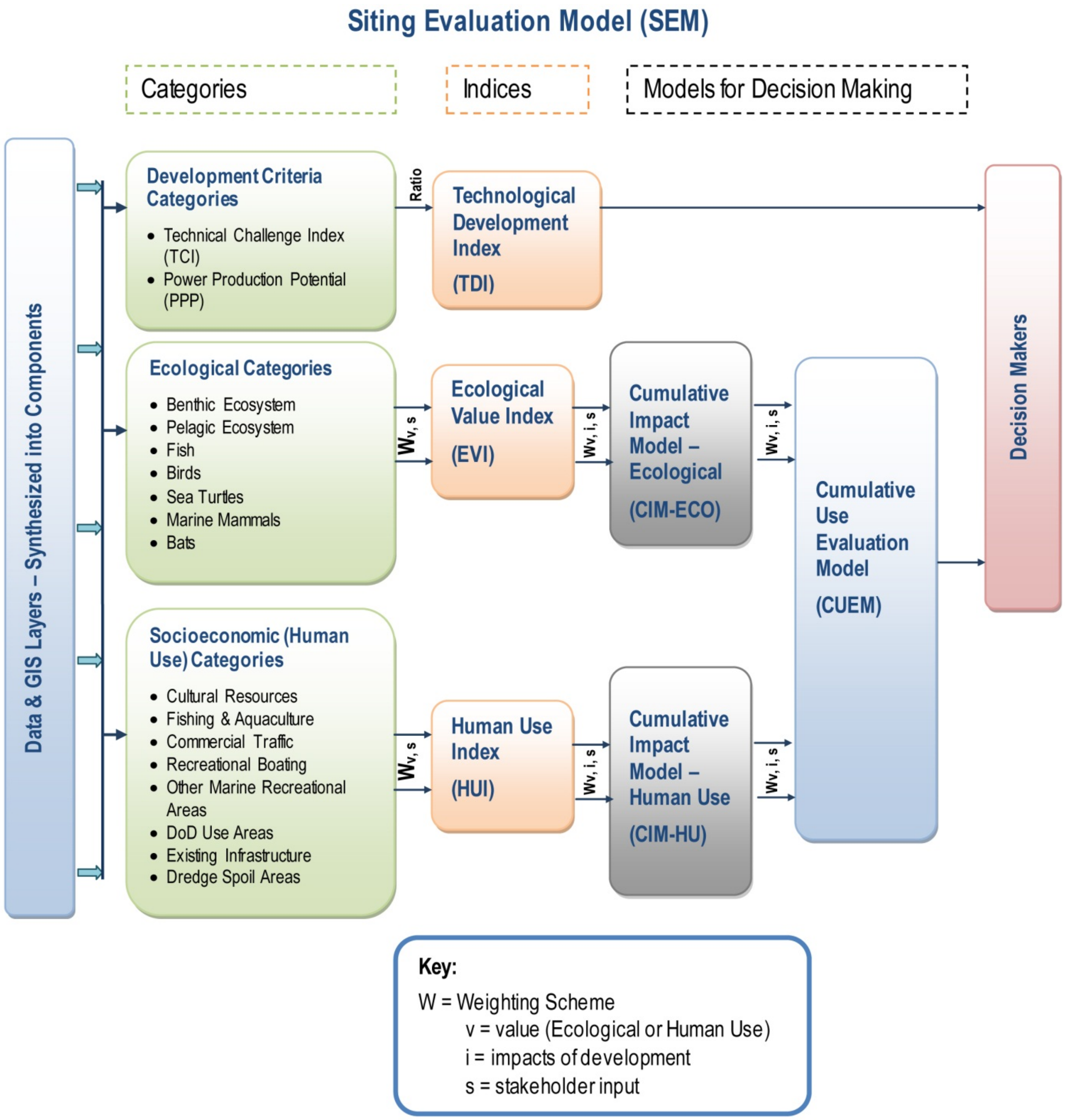


Figure 2. Framework for a Siting Evaluation Model for decision-makers, including indices of technological development potential, ecological value, and human use.

6.3 Objectives 3 and 4—Integrate Ecological Data Inputs and Weighting Factors

First, ecological data inputs representing various components (e.g., individual species) are integrated into a series of category-level EVMs (e.g., birds) using a variety of weighting factors. We used weighting schemes for “Proportional importance to regional-global scale”, “Resource and protection status”, “Ecosystem component productivity” and “Data robustness”. These weighting schemes were applied at the component level, i.e., that of individual species/resources. The “Proportional importance to regional-global scale” and “Resource and protection status” weighting schemes were applied to individual species/groups of birds, marine mammals, sea turtles, and fish/invertebrates. The “Ecosystem component productivity” weighting scheme was applied to the pelagic and benthic environment components. The “Data robustness” weighting scheme was applied to all components. Application of these weighting schemes results in category-level EVMs that are then compiled into an EVI (Figure 3). The weighting factors quantify the potential impacts of ORE development and are used to modify the ecological category weights in the EVI in order to generate the CIM-Eco index. One of the strengths of this approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented.

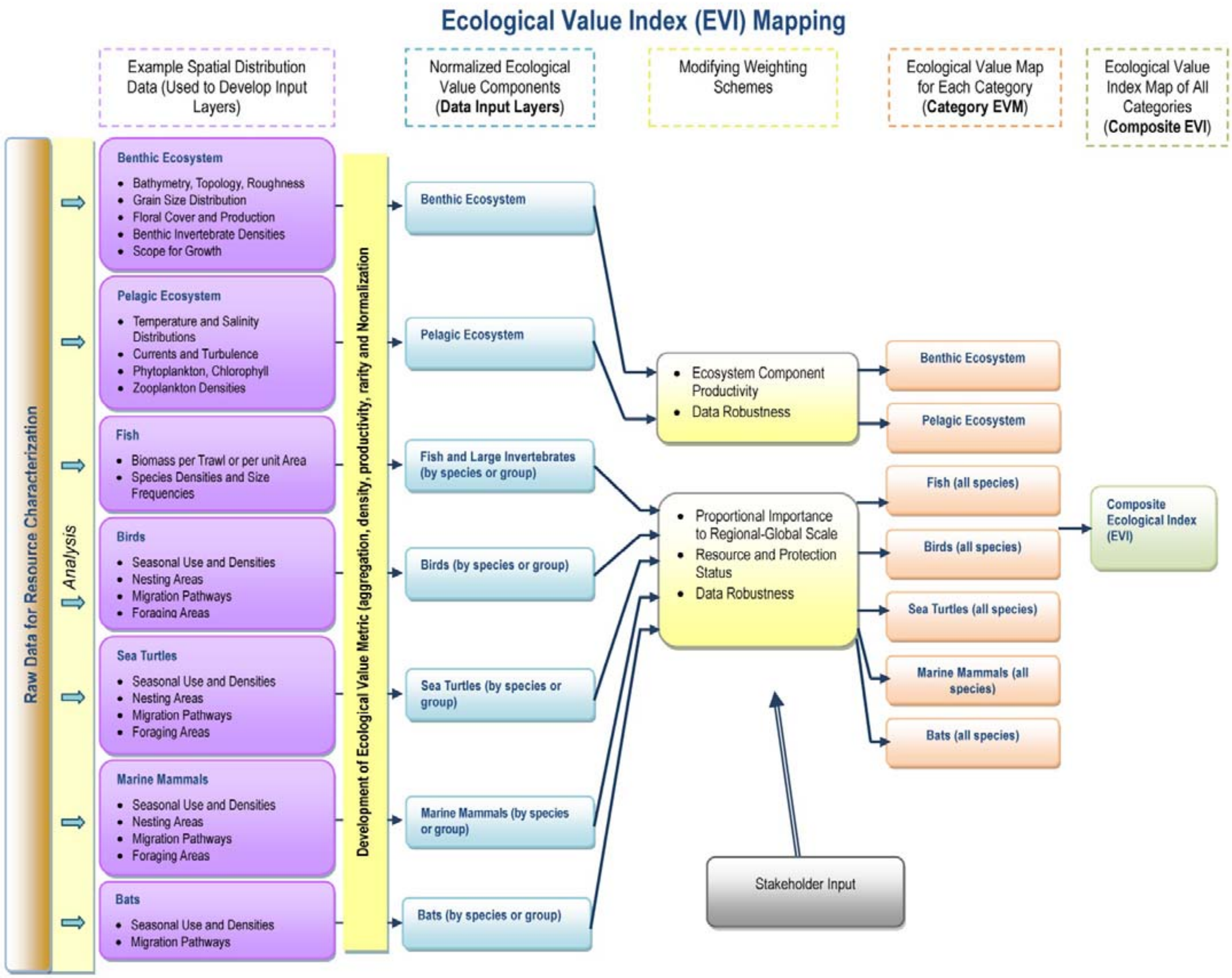


Figure 3. Flow Chart for Development of Ecological Value Maps (EVMs) and the Ecological Value Index (EVI).

6.4 OBJECTIVE 5— GENERATE A CUMULATIVE IMPACT MODEL (CIM-ECO)

The CIM-Eco portion of the SEM is generated by the application of two intermediate products, category-level EVMs, and a composite EVI. A model calculation tool (the CIM-Eco Calculator) was supplied as an associated deliverable with the Task 2.3 Report. Using this tool, other weighting schemes may be discussed and evaluated as issues and concerns arise. One of the strengths of the model approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented. The applications of the CIM-Eco model in the Rhode Island SAMP area (e.g., Figure 4) showed that there are several challenges in applying ecological valuation as a useable tool for ORE siting. The most important factors influencing the results of the model are: (1) defining the appropriate scale for the valuation effort; (2) a lack of standardized input data; and (3) patchy or inconsistent data availability/coverage necessitating application of interpolation models or spreading algorithms with uncertain underlying assumptions.

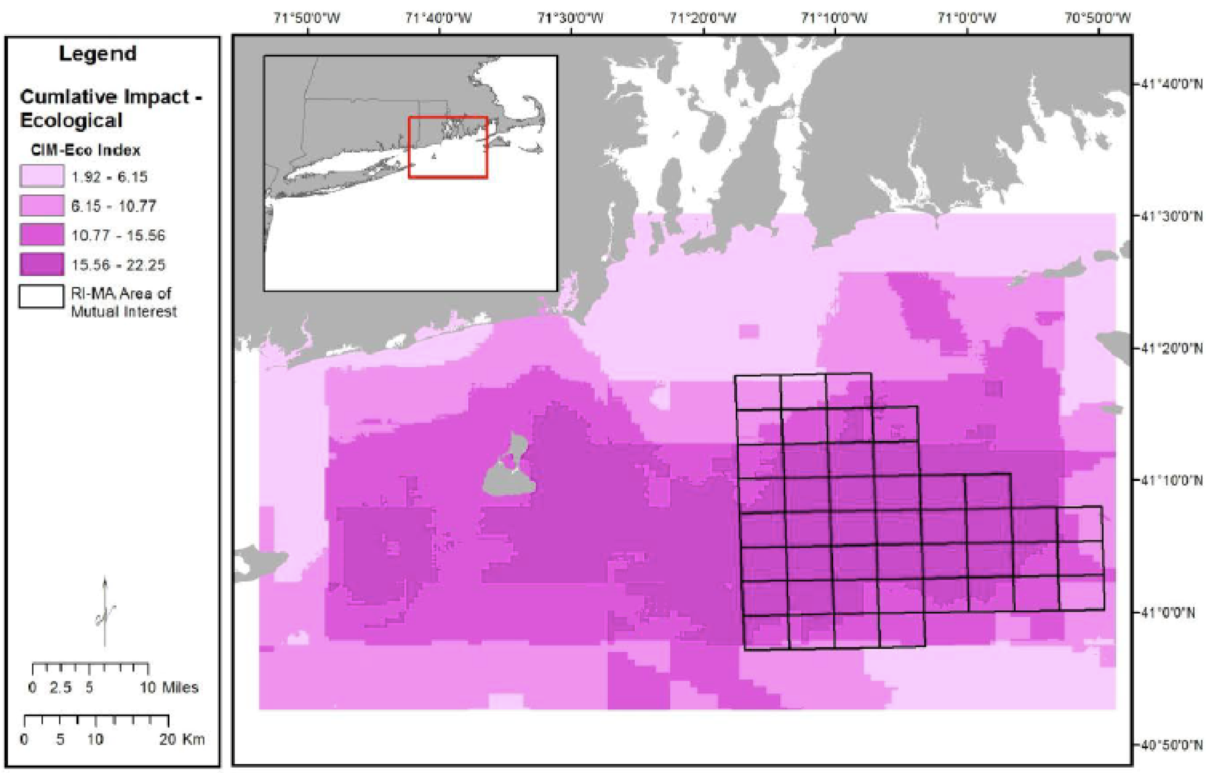


Figure 4. Example CIM-Eco results for a commercial-scale wind energy development with lattice foundations.

LIST OF REFERENCES

ABPmer Ltd, et al., 2010. A Further Review of Sediment Monitoring Data. Commissioned by COWRIE Ltd (project reference ScourSed-09), 115 pp.

Allen, B. M., and R. P. Angliss. 2010. Alaska Marine Mammal Stock Assessments, 2009. NOAA Technical Memorandum NMFS-AFSC-206. National Marine Fisheries Service, Seattle, WA.

AMEC Wind Energy. 2002. Lynn Offshore Environmental Impact Assessment.

Banning, E.B. 2002. Archaeological Survey, 1st edition. Springer, New York, NY.

Barrow Offshore Wind Ltd. 2009. Barrow Offshore Wind Farm Post-Construction Monitoring Report. DONG Energy, Copenhagen, Denmark.

Boehlert, G.W., G.R. McMurray, and C.E. Tortorici, editors. 2008. Ecological Effects of Wave Energy Development in the Pacific Northwest. NOAA Technical Memorandum NMFS-F/SPO-92. National Marine Fisheries Service, Seattle, WA.

BOEMRE (Bureau of Ocean Energy Management, Regulation & Enforcement). not dated. Geological and Geophysical (G&G) Technical and Report Guidelines for Physical Characterization Surveys and Archaeological Surveys (draft). Bureau of Ocean Energy Management, Regulation, and Enforcement, Office of Offshore Alternative Energy Programs, Herndon, VA. 17pp. Available online at: http://www.boemre.gov/offshore/RenewableEnergy/PDFs/GGARCH4-11-2011.pdf.

Brandt, M.J., A. Diederichs, K. Betke, and G. Nehls. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series, 421:205-216.

Brown, C.J., and J.S. Collier. 2008. Mapping benthic habitat in regions of gradational substrata: An automated approach utilising geophysical, geological, and biological relationships. Estuarine Coastal and Shelf Science, 78: 203-214.

BSH (Bundesamt für Seeschifffahrt und Hydrographie). 2007. Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK 3). BSH-Nr. 7003, Bundesamt für Seeschifffahrt und Hydrographie, Hamburg and Rostock, Germany. Available online from: http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf

Camphuysen, C.J., A.D. Fox, M.F. Leopold, and I.K. Petersen. 2004. Towards Standardised Seabirds at Sea Census Techniques in Connection with Environmental Impact Assessments for Offshore Sind Farms in the U.K. A Comparison of Ship and Aerial Sampling Methods for Marine Birds, and Their Applicability to Offshore Wind Farm Assessments. COWRIE report, BAM- 02-2002. Koninklijk Nederlands Instituut Onderzoek der Zee, Den Burg, Netherlands. 39pp. Available online at: http://jncc.defra.gov.uk/pdf/Camphuysenetal2004_COWRIEmethods.PDF.

Carey, J.M., and M.J. Keough. 2002. The variability of estimates of variance, and its effect on power analysis in monitoring design. Environmental Monitoring and Assessment, 74: 225-41.

Carretta, J.V., K.A. Forney, M.S. Lowry, J. Barlow, J. Baker, D. Johnston, B. Hanson, R.L. Brownell, Jr., J. Robbins, D.K. Mattila, K. Ralls, M.M. Muto, D. Lynch, and L. Carswell. 2010. U.S. Pacific Marine Mammal Stock Assessments: 2009. NOAA Technical Memorandum NMFS-SWFSC-453. National Marine Fisheries Service, La Jolla, CA.

CEFAS. 2010. Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA License Conditions.

Crowder, L., and E. Norse. 2008. Essential ecological insights for marine ecosystem-based management and marine spatial planning. Marine Policy 32: 772-778.

Daan, R., M. Mulder, and M.J. N. Bergman. 2009. Impact of windfarm OWEZ on the local macrobenthos community. Report OWEZ_R_261_T1_20091216, 77 pp.

Degraer, S., and R. Brabant (Eds.). 2009. Offshore wind farms in the Belgian part of the North Sea: State of the art after two years of environmental monitoring; Chapter 12: Recommendations for a future monitoring of wind farms in Belgium's marine waters. Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. pp. 275-279.

de Lestang, S., N. Caputi, J. How, R. Melville-Smith, A. Thomson, and P. Stephenson. 2011. Draft Stock Assessment for the West Coast Rock Lobster Fishery. Government of Western Australia, Department of Fisheries.

Derous, S., T. Agardy, H. Hillewaert, K. Hostens, G. Jamieson, L. Lieberknecht, J. Mees, I. Mouleart, S. Olenin, D. Paelinckx, M. Rabaut, E. Rachor, J. Roff, E.W.M. Stienen, J.T. van der Wal, VT, van Lancker, E. Verfaillie, M. Vincx, J.M. Weslawski, and S. Degraer. 2007a. A concept for biological valuation in the marine environment. Oceanologia 49(1): 99-128.

Derous, S., M. Austen, S. Claus, N. Daan, J.C. Dauvin, K. Deneudt, J. Depestele, N. Desroy, H. Heessen, K. Hostens, A. Husum Marboe, A.K. Lescrauwaet, M.P. Moreno, M. Mouleart H. Rees, A. Ressurreicao, J. Roff, P. Talhadas Santos, J. Speybroeck, E.W.M. Stienen, A. Tatarek, T.T. Hofstede, M. Vincx, T. Zarzycki, and S. Degraer. 2007c. Building on the concept of marine biological valuation with respect to translating it to a practical protocol: Viewpoints derived from a joint ENCORA-MARBEF initiative. Oceanologia 49(4): 1-8.

Derous, S., E. Verfaille, V. Van Lancker, W. Cortens, E.W.M. Steinen, K. Hostens, I. Mouleurt, H. Hillewaert, J. Mees, K. Deneust, P. Deckers, D. Cuvelier, M., Vincx, and S. Degraer. 2007b. A Biological Valuation Map for the Belgian Part of the North Sea: BWZee Final Report. Belgian Science Policy, Brussels, Belgium.

Derweduwen, J., S. Vandendriessche, and K. Hostens. 2010. Monitoring of the effects of the Thorntonbank and Bligh Bank wind farms on the epifauna and demersal fish fauna of soft-bottom sediments: Thorntonbank: status during construction (T2), Bligh Bank: status during construction (T1). In: Degraer, S., Brabant, R. & Rumes, B. (Eds.) 2010. Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. pp. 105-131.

DONG Energy 2006. Danish Offshore Wind - Key Environmental Issues. Chapter 5: Fish. DONG Energy, Vattenfall, the Danish Energy Authority and The Danish Forest and Nature Agency, Denmark.

Douvre, F. 2008. The engagement of stakeholders in the marine spatial planning process. Marine Policy 32: 762-771.

Drewitt, A.L., and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148: 29-42.

Ehler, C. 2008. Conclusions: Benefits, lessons learned, and future challenges of marine spatial planning. Marine Policy 32: 840-843.

Emu, Ltd, 2006. Kentish Flats Windfarm Development: Macrobenthic ecology study - 2005; Final Report 2006. Southampton, UK. 270 pp.

ESS Group, Inc., 2011. Cape Wind Energy Project: Construction and Operations Plan, Appendix H: Selected Regulatory Permits and Approvals and Correspondence. Cape Wind Associates, LLC. 163 pp.

FERC, 2006. Title 18: Conservation of Power and Water Resources Chapter 1: Federal Energy Regulatory Commission, Department of Energy, Part 5: Integrated license application process. http://www.access.gpo.gov/nara/cfr/waisidx_06/18cfr5_06.html; Last accessed 7/10/11.

FERC, 2010. Reedsport OPT Wave Park Settlement Agreement. FERC No. 12713, Douglas County, Oregon. 263 pp.

Fox, A.D., M. Desholm, J. Kahlert, T.K. Christensen, and I.K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148: 129-144.

Gill, A.B., Y. Huan, I. Gloyne-Phillips, J. Metcalfe, V. Quayle, J. Spencer, and V. Wearmouth. 2009. EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. COWRIE / Cranfield University / CEFAS, CIMS, CMACS (Center for Marine And Coastal Studies, Ltd).

Grecian, W.J., R. Inger, M.J. Attrill, S. Bearhop, B.J. Godley, M.J. Witt, and S.C. Votier. 2010. Potential impacts of wave-powered marine renewable energy installations on marine birds. Ibis 152: 683-697.

Grift, R.E., A.S. Couperus, and M.S. Ybema. 2003. Base line studies North Sea wind farms: strategy of approach for pelagic fish. RIVO-Netherlands Institute for Fisheries Research. Report RKZ-1273. 20 pp.

Henfridsson, U., V. Neimane, K. Strand, R. Kapper, H. Bernhoff, O. Danielsson, M. Leijon, J. Sundberg, K. Thorburn, E. Ericsson, and K. Bergman. 2007. Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak. Renewable Energy 32: 2069–2084.

Jarvis, S., J. Allen, N. Proctor, A. Crossfield, O. Dawes, A. Leighton, L. McNeill, and W. Musk. 2004. North Sea Wind Farms: NSW Lot 1 Benthic Fauna. Final Report. University of Hull. 91 pp.

JNCC, NE, & CCW (Joint Nature Conservation Commission, Natural England, and Countryside Council for Wales). 2010. The protection of marine European protected species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area. Joint Nature Conservation Commission, Natural England, and Countryside Council for Wales.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (Eubalaena glacialis). Marine Mammal Science 6: 278–291.

Langton, R., I.M. Davies, and B.E. Scott. 2011. Seabird conservation and tidal stream and wave power generation: Information needs for predicting and managing potential impacts. Marine Policy 35: 623-630.

Leijon, M., H. Bernhoff, M. Berg and O. Ågren. 2003. Economical considerations of renewable electric energy production – especially development of wave energy. Renewable Energy 28: 1201–1209.

Leonhard, S., and J. Birklund. 2006. Infauna, epifauna and vegetation; Change in diversity and higher biomass. Pages 44-62 in: Danish Offshore Wind: Key Environmental Issues. DONG Energy, Vattenfall, The Danish Energy Authority, and the Danish Forest and Nature Agency, Skaerbaek, Denmark.

Maclean, I.M.D., L.J. Wright, D.A. Showler, and M.M. Rehfisch. 2009. A review of assessment methodologies for offshore wind farms. British Trust for Ornithology, COWRIE Ltd., United Kingdom.

Martec Limited. 2004. Effects of pipelines/gathering lines on snow crab and lobster. Martec Limited, CEF Consultants Ltd, DRDC Atlantic, St. Francis Xavier University, Calgary.

Meibner, K., and H. Sordyl. 2006. Ecological research on offshore wind farms: International exchange of experiences; Chapter 1: Literature review of offshore wind farms with regard to benthic communities and habitats. German Federal Agency for Nature Conservation. pp 1-46.

Minerals Management Service (MMS). 2001. Development and Design of Biological and Physical Monitoring Protocols to Evaluate the Long-term Impacts of Offshore Dredging Operations on the Marine Environment. MMS International Activities and Marine Minerals Division. MMS 2001-089.

MMS (Minerals Management Service). 2005a. Appendix No. 1. Guidelines for Archaeological Resource Surveys. Notice to Lessees and Operators of Federal Oil, Gas, and Sulphur Leases and Pipeline Right-of-Way Holders in the Outer Continental Shelf, Gulf of Mexico OCS Region, NTL2005-G07. MMS Gulf of Mexico OCS Region. 16pp. Available online at: www.boem.gov/Regulations/Notices-To-Lessees/2005/05-G07.aspx.

MMS (Minerals Management Service). 2005b. Notice to Lessees and Operations of Federal Oil and Gas Leases in the Alaska Outer Continental Shelf Region. NTL No. 05-A03. Available online at: http://www.alaska.boemre.gov/regs/NTL%202005-A031.pdf.

MMS (Minerals Management Service). 2006. Notice to Lessees and Operators (NTL) of Federal Oil and Gas Leases and Pipeline Right of Way (ROW) Holders on the Outer Continental Shelf (OCS), Gulf of Mexico OCS Region (GOMR). NTL No. 2006-G07. 57pp. Available online at: http://www.gomr.boemre.gov/homepg/regulate/regs/ntls/2006%20NTLs/06-g07.pdf.

MMS (Minerals Management Service). 2008. Notice to Lessees and Operators (NTL) of Federal Oil and Gas Leases and Pipeline Right of Way (ROW) Holders on the Outer Continental Shelf (OCS), Gulf of Mexico OCS Region (GOMR). NTL No. 2008-G20. 5pp. Available online at: http://www.gomr.boemre.gov/homepg/regulate/regs/ntls/2008NTLs/08-g20.pdf.

MMS (Minerals Management Service). 2007. Final Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use Facilities on the Outer Continental Shelf. OCS EIS/EA MMS 2007-046. U.S. Dept. of the Interior, Minerals Management Service, Herndon, VA. Available online at: http://ocsenergy.anl.gov/documents/fpeis/index.cfm.

Moein-Bartol, S., and J.A. Musick. 2003. Sensory biology of sea turtles. Pages 79-102 in P.L. Lutz, J.A. Musick, and J. Wyneken, eds. The Biology of Sea Turtles, Volume II. Boca Raton, Florida: CRC Press, Boca Raton, FLInc.

NRC (National Research Council). 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academies Press, Washington, DC.

National Research Council (NRC). 2007. Environmental Impacts of Wind-Energy Projects. National Academies Press, Washington, DC.

NWP Offshore Limited. 2008. North Hoyle Offshore Wind Farm - Final Annual FEPA Monitoring Report and Five Year Monitoring Program Summary. Npower Renewables Limited, Berkrshire, UK.

O'Hara, J., and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, Caretta caretta, to low frequency sound. Copeia 1990: 564-567.

OSPAR Commission. 2004. Problems and Benefits Associated With the Development of Offshore Wind-Farms. Publication 212/2004.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR Commission. 2006. Review of the Current State of Knowledge on the Environmental Impacts of the Location, Operation and Removal/Disposal of Offshore Wind-Farms; Status Report April 2006. Publication 278/2006.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR Commission. 2008. Assessment of the Environmental Impact of Offshore Wind-Farms. Publication 385/2008.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR, 2002. Joint Assessment and Monitoring Programme (JAMP) guidelines on quality assurance for biological monitoring in the OSPAR area. Ref no. 2002-15, 38 pp.

PCAD Working Group. 2010. Introduction and progress of a working group on the population consequences of acoustic disturbance. IWC Scientific Committee meeting document SC/62/WW5. International Whaling Commission, Cambridge, UK.

Pelc, R., and R. M. Fujita. 2002. Renewable energy from the ocean. Marine Policy 26: 471-479.

Percival, S.M. 2001. Assessment of the Effects of Offshore Wind on Birds. DTI/Pub URN 01/1434. Dept. of Trade and Industry, London, UK.

Percival, S.M. 2003. Birds and Wind Farms in Ireland: A Review of Potential Issues and Impact Assessment. Ecology Consulting, Durham, UK.

Polagye, B., B. Van Cleve, A. Copping, and K. Kirkendall. 2010. Environmental Effects of Tidal Energy Development. Proceedings of a Scientific Workshop. University of Washington, Seattle. March 22-25, 2010. NOAA Technical Memorandum NMFS F/SPO-116. National Marine Fisheries Service, Seattle, WA.

Popper, A.N., and M.C. Hastings. 2009. The effects of anthropogenic sources of sound on fishes. Journal of Fish Biology, 75: 455-489.

Reedsport OPT Wave Park, LLC. 2010. Joint Explanatory Statement for the Settlement Agreement Dated July 28, 2010 Regarding the Construction and Operation of the Reedsport

OPT Wave Park, FERC No. 12713, Douglas County Oregon.. Reedsport OPT Wave Park LLC, Pennington, NJ. Available online at: http://elibrary.ferc.gov/idmws/File_list.asp?document_id=13836497.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1969. Hearing in the giant sea turtle, Chelonia mydas. Proceedings of the National Academy of Sciences of the USA 64: 884-890.

Snohomish County Public Utility District No. 1. 2009. Draft Environmental Report. Admiralty Inlet Pilot Tidal Project. FERC Project No. 12690. Snohomish County Public Utility District, Everett, WA.

Spaulding, M.L., A. Grilli, C. Damon, and G. Fugate. 2010. Application of Technology Development Index and principal component analysis and cluster methods to ocean renewable energy facility siting. Marine Technology Society Journal 44(1): 8-23.

St. Martin, K., and M. Hall-Arber. 2008. The missing layer: Geo-technologies, communities, and implications for marine spatial planning. Marine Policy 32: 779-786.

Stokesbury, K.D.E., and B.P. Harris. 2006. Impact of limited short-term sea scallop fishery on epibenthic community of Georges Bank closed areas. Marine Ecology Progress Series, 307: 85-100.

Teilmann, J., J. Tougaard, and J. Carstensen. 2006. Summary on harbour porpoise monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Van den Eynde, D., R. Brabant, M. Fettweis, F. Francken, J. Melotte, M. Sas, and V. van Lancker. 2010. Monitoring of hydrodynamic and morphological changes at the C-Power and Belwind offshore windfarm sites – A synthesis.

van der Wal, D., R.M. Forster, F. Rossi, H. Hummel, T. Ysebaert, F. Roose, F., and P.M. J. Herman. 2011. Ecological evaluation of an experimental beneficial use scheme for dredged sediment disposal in shallow tidal waters. Marine Pollution Bulletin 62: 99-108.

Verdant Power, LLC. 2010. Roosevelt Island Tidal Energy Project, FERC No. 12611, Final Kinetic Hydropower Pilot Licence Application, Volume 4, Part 1: Proposed Monitoring Plans, RITE Monitoring of Environmental Effects (RMEE). Verdant Energy, LLC, New York, NY. http://www.theriteproject.com/uploads/VPRITE-FLAVol4-Part1of3.pdf

Wahlberg, M. and H. Westerberg. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Progress Series, 288: 295-309.

Ware, S., S.G. Bolam, and H.L. Rees. 2010. Impact and recovery associated with the deposition of capital dredgings at UK disposal sites: lessons for future licensing and monitoring. Marine Pollution Bulletin 60: 79-90.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2009. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2009. NOAA Technical Memorandum NMFS-NE-213. National Marine Fisheries Service, Woods Hole, MA.

Westerberg, H., and I. Lagenfelt. 2008. Sub-sea Power Cables and the Migration Behaviour of the European Eel. Fisheries Management and Ecology 15(5-6): 369-375.

TASK 1.2

REPORT ON MONITORING THE POTENTIAL EFFECTS OF OFFSHORE RENEWABLE ENERGY

This deliverable, along with the Task 1.3 report entitled *A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction* serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This report focuses on understanding the potential effects associated with offshore renewable energy (ORE) and which effects need to be monitored in the future, whereas the Task 1.3 report reviews all the different monitoring techniques that have been performed to date on ORE or in other marine construction industries

TASK 1.2

REPORT ON MONITORING THE POTENTIAL EFFECTS OF OFFSHORE RENEWABLE ENERGY

Contributing Authors:

Michelle Carnevale, University of Rhode Island (URI) Coastal Resources Center
John King, URI Graduate School of Oceanography
Robert Kenney, URI Graduate School of Oceanography
Peter Paton, URI College of Environmental and Life Sciences
Malia Schwartz, URI Graduate School of Oceanography
Emily Shumchenia, URI Graduate School of Oceanography
Sarah Smith, URI Coastal Resources Center
Malcolm Spaulding, URI College of Engineering
Kristopher Winiarski, URI College of Environmental and Life Sciences

EXECUTIVE SUMMARY

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.3 report entitled *A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction* serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This report focuses on understanding the potential effects associated with offshore renewable energy (ORE) and which effects need to be monitored in the future, whereas the Task 1.3 report reviews all the different monitoring techniques that have been performed to date on ORE or in other marine construction industries.

The objectives of this report as stated in the contract no. M10PS00152 are to:

1. Identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, birds, and bats from offshore wind energy (OWE) or marine hydrokinetic (MHK, including wave and tidal energy) development on the Outer Continental Shelf (OCS) not discussed within the Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use of Facilities on the Outer Continental Shelf (PEIS) (MMS, 2007).
2. Identify and categorize the level of effect and certainty of each potential effect of OWE and MHK at the following scales:

demonstration scale (Scale 1), commercial scale (Scale 2), and multiple facilities within a region (Scale 3).

3. Outline potential effects that require monitoring at future OWE and MHK facilities and for which protocols will be developed in Year 2.
4. Discuss how data collected during monitoring protocols can be used to support cumulative impact assessments and associated models.

While the PEIS discussed a wide array of resource topics, including both onshore and offshore natural resources, human activities, economics, and infrastructure, the scope of this project and report focuses on: benthic habitat; fish and fisheries; marine mammals; sea turtles; and avian species. In addition, while OWE and MHK devices may be installed along the coast or within coastal waters (under state jurisdiction) the focus of this report is on facilities sited in federal waters of the OCS and therefore under the jurisdiction of the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE).

To identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, and birds from OWE or MHK not discussed within the PEIS, a literature review of studies and reports completed after the 2007 PEIS publication date was conducted. In addition, U.S. resource experts, European researchers and industry members on the Project Advisory Committee for this project were also consulted to ensure all potential effects were included (Appendix A). The results of this extensive literature review found that while there have been many new reports, studies, and proceedings on the effects of ORE, no new potential effects of OWE or MHK have been identified since the publication of the PEIS (see Section 6). Members of the Project Advisory Committee confirmed through multiple meetings and discussions during a year-long process that no new potential effects have been identified.

Once all potential effects were identified, each was categorized according to the level of effect and the level of certainty at each scale of development and for each technology type within the Offshore Renewable Energy Effect Matrix. This matrix was then used as a guidance tool when determining what monitoring protocols were needed. In addition to the matrix, the monitoring requirements established for demonstration MHK projects and OWE projects currently permitted in the U.S. were examined.

Based on the Offshore Renewable Energy Effect Matrix and the input from the Project Advisory Committee, the potential effects for which monitoring protocols will be developed in Year 2 are presented below in Table ES-1.

Table ES-1

Potential Effects for which Monitoring Protocols will be developed in Year 2

Benthic Habitat and Resources	
Scale 1 (Demonstration Scale)	• Scour around device • Changes in median grain size, or organic content • Turbidity during construction/decommissioning • Change in target species abundance and distribution (e.g, species of importance) • Colonization density, composition of communities on foundations
Scale 2 (Commercial Scale)	• Changes to seafloor morphology and structure (compared to pre-construction) • Changes in median grain size, or organic content • Turbidity during construction/decommissioning • Change in target species abundance and distribution (e.g, species of importance) • Change in density, diversity, dominance structure of infauna • Colonization density, composition of communities on foundations • Current speed/direction inside and outside farm
Scale 3 (Multiple Commercial Facilities in a Region)	• Changes to seafloor morphology and structure (compared to pre-construction) • Changes in median grain size, or organic content • Change in target species abundance and distribution (e.g., species of importance) • Change in density, diversity, dominance structure of infauna • Hydrodynamics inside and outside farms throughout region
Fish	
Scale 1	• Reef effects • Blade strikes (tidal power)
Scale 2	• Reef effects • Changes to abundance/distribution • Installation noise effects (for devices requiring pile driving) • Operational noise effects • EMF effects • Blade strikes / pressure gradients (tidal power)
Scale 3	• Reef effects • Changes to abundance/distribution and community composition on regional scale • Installation noise effects (for devices requiring pile driving) • Operational noise effects • EMF effects • Blade strikes / pressure gradients (tidal power)

Table ES-1 (Continued).

Potential Effects for which Monitoring Protocols will be developed in Year 2.

Fisheries	
Scale 1	• Loss of access to grounds
Scale 2	• Catchability during construction • Catchability during operation • Loss of access to grounds • Changes in species distribution • Reef effects (aggregation)
Scale 3	• Catchability during construction • Catchability during operation • Loss of access to grounds • Changes in species distribution • Reef effects (aggregation)
Avian	
Scale 1	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Scale 2	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Scale 3	• Vessel strikes causing chemical spill • Displacement/ attraction • Barrier effects – effects on foraging, roosting, migratory movements • Collision mortality
Marine Mammals and Sea Turtles	
Scale 1	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes
Scale 2	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes
Scale 3	• Vessel strikes • Noise generated during all stages of development • Disturbance or injury during all stages of development • Changes in distribution or migratory routes • Changes in life history and demographics

Monitoring protocols to address these potential effects will be designed to feed into the siting models and cumulative impact assessment tools developed in Year 2. Designing standardized monitoring protocols, siting models and cumulative impact assessment tools in conjunction with one another increases their overall compatibility and effectiveness. Monitoring protocols designed in Year 2 will also be designed using the appropriate spatial and temporal scale for a resource or effect.

TASK 1.2

REPORT ON MONITORING THE POTENTIAL EFFECTS OF OFFSHORE RENEWABLE ENERGY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

BOEMRE	Bureau of Ocean Energy Management Regulation and Enforcement
EFH	Essential Fish Habitat
MHK	Marine Hydrokinetic
NOPP	National Oceanographic Partnership Program
OCS	Outer Continental Shelf
ORE	Offshore Renewable Energy
ORED	Offshore Renewable Energy Development
OWE	Offshore Wind Energy
PEIS	Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use of Facilities on the Outer Continental Shelf

1. INTRODUCTION

Offshore renewable energy (ORE) technologies have the potential to affect the natural resources and existing human uses on the Outer Continental Shelf (OCS). The potential environmental effects associated with a project will vary based on the type of technology and its design, and siting. Environmental effects will vary over the project lifecycle as each stage of development (i.e. pre-construction siting, construction, operation, and decommissioning) involve a different set of activities. Furthermore, the scale of the project will also determine the type of effect, as well as its magnitude. Whereas offshore wind energy (OWE) has been developed in Europe, it has not yet been developed in the U.S. Moreover, marine hydrokinetic (MHK) technologies remain in the prototype stage in both the U.S. and Europe. Thus, identifying the range and magnitude of potential effects that may result from the development of OWE and MHK facilities is an important first step in designing appropriate monitoring requirements.

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.3 report entitled *A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction* serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This report focuses on understanding the potential effects associated with offshore renewable energy (ORE) and which effects need to be monitored, whereas the Task 1.3 report reviews all relevant monitoring techniques that have been performed to date on ORE or in other marine construction industries.

Because there is limited, or in some cases no monitoring of environmental effects of OWE and MHK, both of these Year 1 deliverables have relied heavily on the input and review of the resource experts, industry representatives and researchers, members of the Project Advisory Committee, and the Topic Area Advisors. For a complete list of Project Advisory Committee members and the Topic Area Advisors see Appendix A.

1.1. OBJECTIVES AND METHODOLOGY

The objectives of this report are as follows:

1. Identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, birds and bats from OWE and MHK development on the OCS not discussed within the PEIS (MMS, 2007).
2. Identify and categorize the level of effect and certainty of each potential effect of OWE and MHK at the following scales: demonstration scale (Scale 1), commercial scale (Scale 2), and multiple facilities within a region (Scale 3).
3. Outline potential effects that require monitoring at future OWE and MHK facilities.
4. Discuss how data collected during monitoring protocols can be used to support cumulative impact assessments and associated models.

To identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, birds and bats from OWE and MHK development on the OCS not discussed within the PEIS, a literature review of studies and reports completed after the 2007 PEIS publication date was completed. In addition, resource experts on the Project Advisory Committee (Appendix A) were also consulted to ensure all potential effects were included.

Once all potential effects were identified, each was then categorized according to the level of impact and the level of certainty at each scale of development and for each technology type. Resource experts completed and reviewed the Offshore Renewable Energy Effect Matrix (described in Section 7.0 and Appendix C) for all types of technology and for each scale of development. The level of effect was based on the current understanding of effects from research and monitoring conducted to date on ORE or other similar offshore marine construction. The level of certainty was based on the amount of evidence currently available from studies conducted on a potential effect. This matrix was then used as a guidance tool when determining what monitoring protocols were needed (Section 8.0). Identifying the potential effects that warrant monitoring will form the foundation for subsequent research to develop monitoring protocols in Year 2.

2. OWE AND MHK TECHNOLOGIES

2.1. OWE TECHNOLOGIES

Offshore wind energy converts the kinetic energy of the wind blowing offshore into electricity. Virtually all of the currently installed offshore wind turbines consist of a rotor with three blades mounted atop a tower and attached to the seafloor by a foundation structure (Figures 1 and 2). While the rotor and tower of offshore wind turbines are similar, there are various types of foundation structures used depending on site specific conditions, including monopiles, gravity base, tripod or lattice jacket and floating foundations.

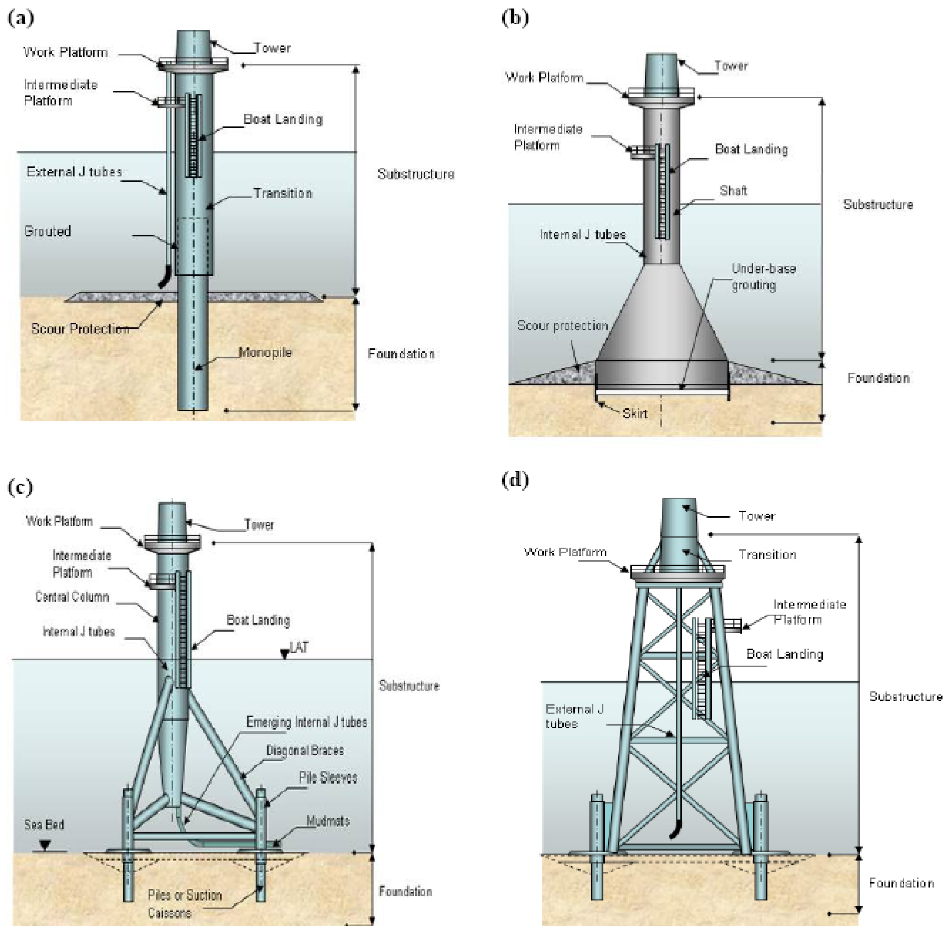


Figure 1. Different support structure types for offshore wind turbines (a) monopile, (b) gravity base, (c) tripod, and (d) jacket (EWEA 2009,*Illustrations by Garrad Hassan and Partners Ltd).

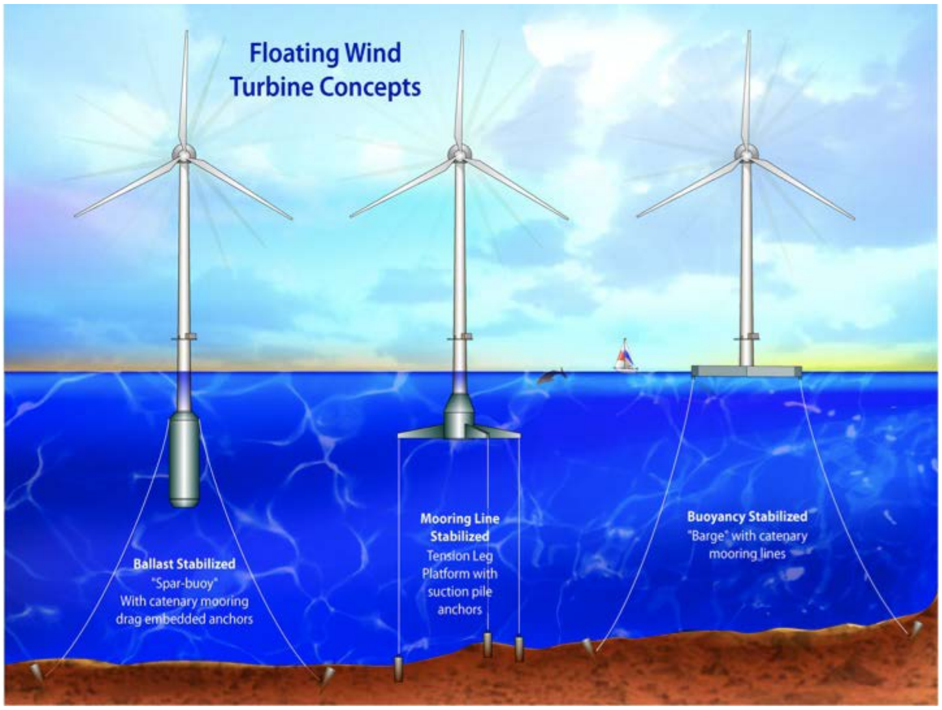


Figure 2. Floating wind turbine designs (Musial 2008b).

Factors influencing the type of foundation technology used includes: water depth, seabed and sub-seabed composition, turbine loads, wave loads, manufacturing requirements and installation procedures (EWEA 2009). To date, the majority of installed offshore wind turbines have used monopile and gravity-base foundations (European Wind Energy Association 2009).

Monopile foundations are made from steel tubes, typically 3.5 to 5.5 m (12 to 18 ft) in diameter that are hammered, drilled, or vibrated 9 to 18 m (30 to 60 ft) into the seabed (MMS 2007). Gravity foundations are constructed of a large concrete structure that rests on the seafloor using weight to stabilize them. Although gravity foundations may be used on multiple bottom types, seabed preparation to create a smooth, flat seabed is required prior to installation (MMS 2007). While monopiles and gravity-based foundations are best suited for shallow water (less than 30 m), tripod and jacketed substructures are considered suitable for transitional water depths of 30 to 60 meters (98.4 to 196.9 feet) and deeper (Musial et al. 2006). Both tripod and jacketed structures are constructed of welded steel tubes fixed atop piling driven into the seabed. Tripod technology is secured to the bottom with 3 piles, compared to the jacketed structures which use 4 driven piles. Jacket technology has been used extensively in the oil and gas industry (Musial et al. 2006). Floating turbine technologies are beginning to be designed and prototyped for use in deeper water depths (EWEA 2009; Musial et al. 2006).

Offshore wind turbine sizes have evolved over time to take advantage of economies of scale by increasing in size and power generating capabilities. The majority of offshore turbines installed to date have power-generating capacities of between 2 and 4 MW, with tower heights taller than 61 m [200 ft] and rotor diameters of 76 to 107 m [250 to 350 ft]. A 3.6-MW turbine weighs 290 metric tons (MT) [320 tons] and stands from 126 to 134 m [413−440 ft] tall, approximately the height of a 30-story building (MMS 2007). Turbine size continues to increase, as turbines rated for 5 MW (with rotor diameters of up to 130 m [425 ft]) are being manufactured. Plans for 7 and 10 MW structures are being developed (EWEA 2009).

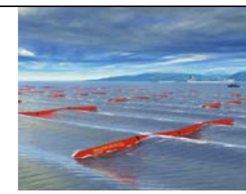
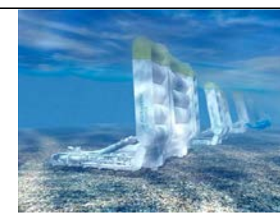
2.2. MHK TECHNOLOGIES

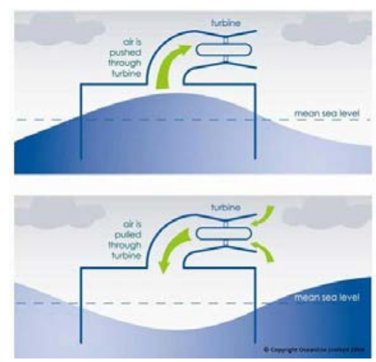
Wave, current and tidal energy technologies are similar in that they all convert the energy associated with moving water into electricity. As a result, collectively all of these technologies can be categorized as MHK energy. Wave energy uses the kinetic and potential energy of an ocean wave caused by the vertical displacement of the water surface and the oscillatory motion of the water column. Conversely, current and tidal energy technologies use the horizontal motion of ocean currents and tides to generate electricity (DOE 2009). The term marine hydrokinetic energy does not include energy from any traditional hydropower sources such as dams, diversionary structures, or impoundment for electric power purposes. Marine hydrokinetic energy devices are primarily still in the conceptual or demonstration phase and have not been deployed as part of a utility-scale facility in the United States. Consequently, few studies have been able to provide direct evidence of the environmental effects associated with these devices.

There are at least eight types of marine hydrokinetic technology (Table 1). Wave energy technologies include various types of devices including: point absorbers, attenuators, oscillating wave surge converters, oscillating water column, overtopping devices, and submerged pressure differential devices. Current and tidal energy converters include horizontal axis turbines, ducted horizontal axis turbines, vertical axis turbines, and oscillating hydrofoils (EMEC, 2010).

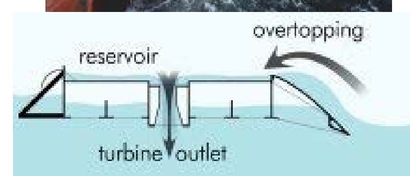
Table 1

Description of the types of MHK energy devices

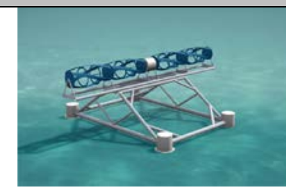
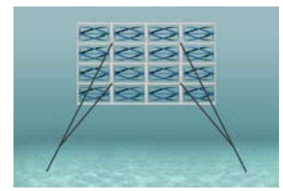
Wave Energy Devices			
Technology Type		**Method of Attachment to the Sea Floor**	**Example Photo**
Point Absorbers:	A floating structure which absorbs energy in all directions through its movements at/near the water surface.	Typically moored, therefore no pile-driving required.	 Photo Source: Ocean Power Technologies
Wave Attenuators:	A floating device which works parallel to the wave direction and effectively rides the waves.	Typically moored, therefore no pile-driving required.	 Photo source: Ocean Power Delivery, Ltd.
Oscillating Wave Surge Converters:	Extracts the energy caused by wave induced currents or surge. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves.	Device sits on sea floor.	

Wave Energy Devices			
Technology Type		**Method of Attachment to the Sea Floor**	**Example Photo**
			 Photo source: Aquamarine Power
Oscillating Water Column Device:	A partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of the airflow. The rotation of the turbine is used to generate electricity. (*Note: this type of device may also be attached to a shoreline structure, however for the purposes of this study only the offshore technology is considered).	Typically moored, therefore no pile-driving required.	 

Wave Energy Devices

Technology Type		Method of Attachment to the Sea Floor	Example Photo
			Photo source: Oceanlinx
Overtopping Device:	Physically captures water from waves which is held in a reservoir above sea level, before being returned to the sea through conventional low-head turbines which generates power.	Typically moored, therefore no pile-driving required.	   Photo Source: Wave Dragon
Axial Flow Open Rotors, Bottom Mounted or Floating/Moored	2 or 3 bladed structures, most are completely submerged underwater, however some have structures above the water used to raise and lower the device.	Bottom mounted devices are secured to the bottom by a driven pile, floating or moored devices are secured to the bottom with an anchoring or	

Wave Energy Devices			
Technology Type		**Method of Attachment to the Sea Floor**	**Example Photo**
		mooring system.	Photo source: Sea Gen  Photo Source: Verdant Power, Inc.  Photo Source: SMD Hydrovision

Technology Type		Method of Attachment to the Sea Floor	Example Photo
Cross Flow Open Rotors, Bottom Mounted or Floating/Moored	Blades run horizontally on these devices. Some designs stack multiple rotors on top of one another.	Bottom mounted devices may be secured to the bottom by driven piles, floating or moored devices are secured to the bottom with an anchoring or mooring system.	  Photo source: Ocean Renewable Power Co.
Shrouded Axial Flow Rotors, Bottom Mounted or Floating/Moored	Rotor is shrouded or covered around the outside, with the generator located along the outside rather than in the center of the device. These are relatively slow moving devices.	Bottom mounted devices may be secured to the bottom by driven piles, gravity-based foundations. Floating or moored devices are secured to the bottom with an anchoring or mooring system.	 Photo source: Open Hydro

The greatest potential for wave energy exists where the strongest winds and largest fetch occurs, which in general corresponds to temperate latitudes between 40° and 60° north and south (Pelc and Fujita 2002). Furthermore, because global winds tend to move west to east across ocean basins, wave resources on the eastern boundaries of oceans also tend to be greater than those on the western edges since the fetch, or the distance a wave travels, is longer (Pelc and Fujita 2002; Musial 2008a). Therefore, in the U.S. the greatest potential for wave energy development occurs on the west coast of North America, as a result of the wind resources that move across the Pacific Ocean (Musial 2008a; Hagerman 2001).

The availability of tidal or current energy is very site specific, as tidal range and current velocity is amplified by factors such as shelving of the sea bottom, funneling in estuaries, reflections by large peninsulas, and resonance effects when tidal wave length is about 4 times the estuary length (Pelc and Fujita 2002). Utility-scale tidal energy requires large tidal ranges and strong tidal currents to produce sufficient energy to be feasible. In stream tidal energy typically requires velocities greater than 1.5- 2 m/sec [3-4 knots] (Spaulding 2008; Pelc and Fujita 2002).

2.3. Underwater Transmission Cables, Offshore Substations and Scour Protection

OWE and MHK facilities share the need for the installation of associated infrastructure to support its operation and transport generated electricity back to the mainland. Underwater transmission cables create a network of low voltage cables within the OWE or MHK facility and a higher voltage cable that connects the facility to the onshore electricity grid. Depending on the size of the facility and its distance from its shore side connection point, transmission cables may be high voltage AC (alternating current) or DC (direct current). DC cables are currently the more expensive option, but are likely to be used over long distances because there is less transmission loss compared to AC (BERR 2008). Cables are usually buried within the sediment when installed offshore on the OCS. Where cables cannot be buried (e.g. hard sea bottoms), cables can be drilled through the substratum or covered with a ballast specifically designed for cable protection (OSPAR 2009; BERR 2008).

Offshore substations, also referred to as the electric service platforms, contain transformers that convert the electricity produced to a higher voltage before transmitting back to shore. Offshore substations are used for larger scaled projects or those located far from the onshore interconnection point.

The movement and transport of surface sediments along the seafloor by currents, tidal circulation, and storm waves can undermine ORE foundations or anchoring structures used to attach the device to the seafloor by removing sediments or scouring away portions of the seafloor that are supporting the structure. Buried underwater transmission cables may also be affected by scour. Scour protection such as boulders, grout bags, and grass mattresses may be used to minimize the effects of scouring on the seafloor topography (MMS 2007).

3. DESCRIPTION OF STAGES OF DEVELOPMENT

3.1. Pre-construction

The pre-construction stage involves all activities associated with siting the location of an offshore wind, wave or hydrokinetic energy facility, the assessment of physical and biological characteristics specific to a site, and the permitting/review process of a project proposal by the appropriate federal, state and local agencies. The entire pre-construction period may last many years depending on the project size and scope. Meteorological towers or buoys are also likely to be installed during this stage to collect continuous data on wind speed and direction, wave or amplitude, period and direction or current speed or direction. Developers must also investigate the seabed topography and substrate composition of a proposed site to engineer the appropriate foundation/mooring system and installation techniques for extraction devices and transmission lines.

3.2. Construction

The construction stage of development is the period in which the turbines, substructures and foundations, moorings, cables and offshore substations are installed at the project site. Various construction vessels, barges and equipment are required, some of which are specialized for the particular task. Transport barges are used to carry towers, blades, nacelles, MHK devices, anchoring systems, scour protection and foundation structures from the onshore staging areas to the project site.

OWE and bottom mounted MHK foundations, substructures, towers and rotors are installed using a jack-up barge outfitted with a crane which lifts and positions structures into place. To stabilize the position of the jack-up barge, four to six legs may be deployed. These legs allow the barge to be raised up to a suitable working elevation (MMS 2009). Vessels equipped with pile driving rams or vibratory hammers embed the foundation piles to specified depths. Alternatively, in areas where pile driving is not possible, drilling techniques may also be used to create holes within the seabed for the piles to be placed.

ORE technologies that require piles to be attached to the sea bed include: offshore wind monopile and tripod/lattice jacket foundation types, as well as any bottom mounted current energy devices. Floating devices typically attach to the seafloor with a mooring that does not require the use of piles. In addition, gravity based foundations do not require driven piles as this type of foundation rests on the sea floor.

Cable laying activities are typically performed by vessels towing a jet-plowing device which uses pressurized sea water to carve a trench in the sediments. The jet-plow creates the trench and lays the cable within the trench allowing the disturbed sediments to settle atop the cable. This technique is used for both the inner-array of cables that connect the turbines to the offshore substation and the longer transmission cables that connect the entire facility to the shore side utility grid. The transmission cables connecting the ORE facility to shore may be embedded from three to ten feet (1-3 m) below the seafloor surface (MMS 2007). Once the transmission cable reaches the shore, it is run through a buried conduit installed to protect the cable in the coastal zone. In addition to the vessels directly involved in laying the cables, multiple small auxiliary vessels may be present to provide support and assistance. Cable laying activities may occur continuously, on a 24 hour basis (MMS 2009).

3.3. Operation

Once installed OWE facilities are designed to have an operational life of approximately 25 years. MHK facilities are likely to have a similar operational lifespan, however because MHK projects are currently demonstration scale projects their operational period may be much shorter.

While monitoring and daily operations may be controlled remotely, periodic maintenance visits to the facility by service vessels and crews are required. Periodic maintenance activities may include: regular inspections of all installed structures, preventive maintenance on all equipment, or repairs to any malfunctioning equipment. According to BOEMRE (MMS 2009), approximately five days per year per offshore wind turbine may be anticipated for both planned and unplanned maintenance activities. However, the number of maintenance visits will likely be influenced by the dependability of the technology employed. Therefore, MHK facilities may require more frequent visits.

3.4. Decommissioning

The final stage of an OWE or MHK facility is its decommissioning, in which installed structures are removed from the project site. Decommissioning involves the dismantling and removal of everything, including infrastructure below the mud line. The decommissioning process is largely the reverse of the installation process and uses similar vessels employed during the facility's construction. Cranes would be used to lift away structures, whereas piles may be removed using one or a combination of acetylene cutting torches, mechanical cutting devices, or high pressure water jets (MMS 2009; MMS 2007). Piles are required to be removed to 15 meters [49.2 feet] below the mud line; therefore, the section of the piles below that depth will remain in the seabed after decommissioning. Explosive techniques may also be used for the removal of some platforms if permitted (MMS 2007).

4. SCALES OF DEVELOPMENT

The range and magnitude of potential effects is determined to a great extent by the size and scale of an OWE or MHK facility. There are some effects that occur as the result of the installation of a single device, whereas there are other effects that are not present unless there is a large-scale facility comprised of multiple devices. Moreover, broad scale effects may be the result of multiple large-scale developments constructed in a region. Consequently, examining the range and magnitude of potential effects should take into account the scale of the project.

The potential effects examined in this report are divided into the following three scales: Scale 1 (demonstration scale); Scale 2 (commercial scale); and Scale 3 (multiple facilities installed within the same region). The definitions used for each of these scales are provided below.

Scale 1- Demonstration Scale

Scale 1 represents demonstration projects or prototype testing of OWE or MHK devices (described in Section 2.0). A project in this scale would include 3 devices or less.

Scale 2- Commercial Facility

Scale 2 represents a single large-scale commercial facility, comprised of many OWE or MHK devices. While commercial-scale facilities may vary in size and capacity, for this report facilities comprised of approximately 100 OWE or MHK devices were used during the assessment of potential effects.

Scale 3- Multiple Large-Scale Facilities in a Region

Scale 3 represents multiple large-scale facilities in a region where the effects of one large-scale facility may combine with the effects of another large-scale facility in the area. Essentially, this scale aims to address possible cumulative effects from the placement of multiple facilities in close proximity to one another.

5. THE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR ALTERNATIVE ENERGY DEVELOPMENT AND PRODUCTION AND ALTERNATE USE OF FACILITIES ON THE OUTER CONTINENTAL SHELF

A recent synthesis of the potential effects of OWE and MHK on the OCS was produced by BOEMRE (formerly the Minerals Management Service) in 2007 entitled the *Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use of Facilities on the Outer Continental Shelf* (PEIS). The PEIS was an initial examination of the potential environmental consequences of implementing the Alternative Energy and Alternate Use Program on the OCS and established initial measures to mitigate environmental consequences. The PEIS was a comprehensive assessment of the potential effects posed to all offshore and onshore natural resources, infrastructure and human uses including:

- Ocean and Surface Sediments
- Air Quality
- Ocean Currents and Movements
- Water Quality
- Acoustic Environment
- Hazardous Material and Waste Management
- Electromagnetic Fields
- Marine Mammals
- Marine and Coastal Birds
- Terrestrial Biota
- Fish Resources and Essential Fish Habitat (EFH)
- Sea Turtles
- Coastal Habitat
- Seafloor Habitat
- Areas of Special Concern
- Military Use Areas
- Transportation
- Socioeconomic Resources
- Cultural Resources
- Land Use and Existing Infrastructure
- Visual Resources
- Tourism and Recreation
- Fisheries
- Non-Routine Conditions

While the PEIS discussed a wide array of resource topics, including both onshore and offshore natural resources, human activities, economics, and infrastructure, the scope of this project and report focuses on the following: benthic habitat; fish and fisheries; marine mammals; sea turtles; and bird and bats. In addition, while OWE or MHK devices may be installed along the coast or within coastal waters (under state jurisdiction) the focus of this report is on facilities sited in federal waters of the OCS and therefore under the jurisdiction of the BOEMRE.

The level of impact to each of these resources by OWE or MHK development were characterized using four impact levels ranging from negligible to major (Table 2).

Table 2

Impact Levels Used in the in the PEIS (MMS, 2007)

Impact Level	Definition of Impact Level
Negligible	• No measurable impacts.
Minor	• Most impacts to the affected resource, activity or community could be avoided with proper mitigation. • Impacts would not disrupt the normal or routine functions of the affected activity or community. • If impacts occur, the affected resource will recover completely without any mitigation once the impacting agent is eliminated. • Once the impacting agent is eliminated, the affected activity or community will return to a condition with no measurable effects without any mitigation.
Moderate	• Impacts to the affected resource, activity or community are unavoidable. • The viability of the affected resource is not threatened although some effects may be irreversible, OR the affected resource would recover completely if proper mitigation is applied during the life of the project or proper remedial action is taken once the impacting agent is eliminated. • The affected activity or community would have to adjust somewhat to account for disruptions due to effects of the project, OR once the impacting agent is eliminated, the affected activity or community will return to a condition with no measurable effects if proper remedial action is taken. • Proper mitigation would reduce effects substantially during the life of the project.
Major	• Impacts to the affected resource, activity or community are unavoidable. • The viability of the affected resource may be threatened, AND the affected resource would not fully recover even if proper mitigation is applied during the life of the project or remedial action is taken once the impacting agent is eliminated. • The affected activity or community would experience unavoidable disruptions to a degree beyond what is normally acceptable, AND once the impacting agent is eliminated, the affected activity or community may retain measurable effects indefinitely, even if remedial action is taken. • Proper mitigation would reduce effects somewhat during the life of the project.

A summary table of the results of the PEIS is provided in Appendix B.

Overall, the PEIS identified noise and physical disturbance (e.g. turbidity, sediment disturbance, crushing benthic organisms, and habitat alteration) as the main potential effects to seafloor habitats from pre-construction and construction related activities (Appendix B). The majority of effects to seafloor habitat were categorized as negligible to minor assuming that sensitive seafloor habitats were avoided. The effect of construction and operational noise on benthic species is largely unknown and therefore it is difficult to categorize the level of impact. EMF from transmission cables was also identified as a potential effect to benthic organisms, however more study is needed. In addition, the potential effect of accidental spills or release of chemicals into the water column would vary depending on the type and size of the spill.

However, these types of events are expected to be rare. The use of explosives during decommissioning would also increase the severity of effects on benthic habitat and resources (Appendix B).

The potential effects to fish resources and EFH from pre-construction activities and a meteorological tower were determined to be negligible to minor since they would be short-term, localized and most species could move away from the area. Construction related effects include sediment disturbance and settling, the crushing of benthic organisms, construction noise, disturbance from increased vessel traffic and the potential for accidental release of fuel, hazardous chemicals or material. The PEIS categorized these effects generally as being negligible to minor, with impact levels varying based on species mobility, hearing capabilities and the extent and toxicity of a hazardous spill. During operation, habitat alteration and changes in community composition were categorized as having the greatest level of impact, though this will vary based on the type of habitat and fish species affected and the project size. The effects of lighting, operational noise and electromagnetic fields on fisheries resources and EFH is largely still unknown. Decommissioning effects will likely be negligible to minor, except in the instances where explosives are used to remove structures.

The PEIS does not categorize the impact level of many of the potential effects to fishing from the pre-construction, construction, operation and decommissioning activities of an offshore wind farm as many of the effects vary depending on gear type and project location. In particular, the abundance of a certain species or its catchability by a fisherman may be affected, as well as the potential for gear entanglement or damage. However, the level of impact will vary depending on the fishery or gear type. For some fisheries an OWE or MHK facility may increase fish abundance and catchability due to reef effects. Space use conflicts or exclusions from an area are possible during all phases of a project; however effects during the operational phase are categorized as having the greatest impact on account of the long duration.

The majority of potential effects to marine mammals as characterized by the PEIS are related to the noise associated with pre-construction surveys, pile-driving or other construction related activities, turbine operation or vessel traffic, as well as the risk of ship strikes during all phases of a project. The PEIS states that these effects could be major if the species affected are threatened or endangered. However, compliance with the Endangered Species Act and Marine Mammal Protection Act regulations, and the coordination with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service would ensure that project activities minimize or avoid impacting marine mammal species.

The PEIS recognizes collision with installed structures, avoidance or displacement from habitat during operation and disturbance from construction related activities onshore and offshore as the potential effects with the greatest level of impact on marine and coastal birds. Accidental releases of fuel, hazardous chemicals or other waste may impact marine and coastal birds; however the PEIS characterizes these effects as negligible in most cases; however a large, toxic spill in an area with a high concentration of avian species may produce more severe effects. Pre-construction and decommissioning activities pose negligible effects to marine and coastal birds according to the PEIS evaluation.

Effects to sea turtles listed in the PEIS were similar to those identified for marine mammals. In particular, geological and geophysical surveys conducted during pre-construction, disturbance from cable trenching or onshore construction and the risk of vessel strikes or accidental fuel or chemical spills may pose a greater impact to threatened and endangered sea turtles, especially if they are near breeding or aggregation areas. Operational lighting may pose a moderate to major impact sea turtles hatchlings if it causes them to become disoriented. Avoidance of important sea turtle habitat can minimize the level of impact to individuals and populations of sea turtles. The effects of turbine noise and electromagnetic fields on sea turtles are largely unknown.

Notably, the development of OWE and MHK technologies share many of the same environmental effects, in part due to the similar types of activities associated with pre-construction siting, construction and decommissioning (e.g. geophysical and geological surveys, pile-driving or cable installations, vessel traffic, etc.) However, during operation marine hydrokinetic devices may create a different set of potential effects depending on if the device is comprised of a spinning rotor that may create noise, or may disturb or result in possible collisions with fish, diving birds, marine mammals or sea turtles. The entrainment, entrapment or impingment of larvae, juveniles or adults in or around an MHK device is also a potential effect that differs from offshore wind energy. Because MHK devices vary more depending on the technology type than OWE devices the range of potential effects varies more as well. For example, floating attenuators or point absorbers would likely generate more negligible potential effects compared to a rotating MHK turbine.

However, the degree to which these technologies may affect the natural environment or human activities in the area varies in large part based on the size, scale and design of the facility, as well as site specific conditions. As a result, the potential effects will vary between projects and may even vary between different parts of a project site.

The PEIS synthesized the current understanding in 2007 of OWE and MHK impacts to marine resources and offshore human uses. Building off of these results, the remainder of this report identifies any new potential effects from OWE or MHK not identified in the PEIS. In addition, this report updates and adds to the findings of the PEIS by characterizing the potential effects (both positive and negative) of ORED based on technology type, scale of development and level of certainty.

6. POTENTIAL EFFECTS FROM OWE AND MHK NOT IDENTIFIED IN THE PEIS

At the time the PEIS was published, research on OWE in Europe had been available directly from monitoring reports completed at installed and operational OWE facilities (e.g. Bioconsult A/S 2003; Birkland and Peterson 2004; Carstensen et al. 2006; Desholm 2005a, 2005b; DONG et al. 2006; Edren et al. 2004; Energi E2 A/S 2004; EMU Ltd 2006; Gill et al. 2006; Guillemente et al. 1998, 1999; Ingemansson A.B. 2003; Leonhard and Pedersen 2005; Nedwell et al. 2003; Proctor et al. 2003; DONG Energy and Vattenfall 2006; Petersen et al. 2006; Pettersson 2005; Tougaard et al. 2005) and by academic or government research groups (Gill 2005; Nedwell et al. 2004; Nedwell and Howell 2004; OSPAR 2006; Thomsen et al. 2006). Since 2007, the understanding of potential effects from OWE has been expanded due to an increasing number of published OWE monitoring reports (ABPmer Ltd et al. 2010; Barrow Offshore Wind Ltd 2009; Bergman et al. 2008; Blew et al. 2008; BERR 2008; Bouma and Lengkeek 2009; Brandt et al. 2008; BSH 2007; Daan et al. 2009; Degrarer and Brabant 2009; Degraer et al. 2010; Deiderichs et al. 2008; Edren et al. 2010; Hille Ris Lambers and Hofstede 2009; Kragefsky 2010; Langhammer et al. 2009; NWP Offshore Ltd 2008; OSPAR 2008). In addition to monitoring reports produced by OWE facility operators, a number of recent reports and studies have been published summarizing the lessons learned regarding the effects of OWE on the marine environment (Blew et al. 2008; Boehlert and Gill 2010; Broström 2008; DeepCWind Consortium 2011; Equimar 2009; Wilhelmsson and Malm 2008; Wilhelmsson et al. 2006; Wilhelmsson et al. 2010). Altogether, a review of this most recent literature has revealed no new positive or negative effects from OWE that were not captured in the PEIS. However, the level of understanding of effects at Scales 1 and 2 has progressed.

In contrast to OWE which has been monitored for many years, the MHK industry is still in its infancy. Therefore, to date very little of the available literature on MHK effects has been based on in situ monitoring. A small number of reports or accounts are available based on data collected at demonstration projects (Langhammer and Wilhelmsson 2009; Langhamer et al. 2009; Verdant Power, LLC 2010; Fortune and Ainsworth 2011; Zydlewski 2011). Therefore, the majority of assessments can only infer the range of potential effects of MHK based on expert opinion and what is known about the effects of other offshore industries (Burton et al. 2010; Clark 2006; Boehlert et al. 2008; DOE 2009; Grecian et al. 2010; Boehlert et al. 2008; Boehlert and Gill 2010; Polagye et al.2009; Polagye et al. 2011; Wang et al. 2007; Cada et al. 1997; Equimar 2009). A comprehensive review of the available literature on MHK has also revealed no new potential effects not identified within the PEIS.

In summary, after a comprehensive literature review of reports completed after the PEIS, no new potential effects from OWE or MHK development were identified that were not included with the PEIS. Due to the European experiences with OWE over the past two decades, there is a solid understanding of the range of potential effects that may result from the development of OWE. Conversely, MHK is still in the prototype phase even in Europe, therefore the extent and severity of potential effects posed by this type of technology has been less studied. While the magnitude of a potential effect may vary between sites, to date the PEIS captures the range of potential effects that may result from ORE technologies during all stages of development.

7. POTENTIAL EFFECTS AND THE SCALE OF DEVELOPMENT-

7.1. OFFSHORE RENEWABLE ENERGY EFFECT MATRIX

The first step in designing monitoring protocols for ORE is determining what potential environmental effects require monitoring at each scale of development. To accomplish this, a matrix was developed to systematically assess the various types of potential effects that are associated with a particular ORE technology. The purpose of this matrix was to:

- Synthesize the current understanding on potential effects by technology type;
- Recognize the level of certainty surrounding potential effects based on expert opinion and available scientific evidence; and
- Identify potential effects for recommended monitoring or further scientific research.

Each row of the Offshore Renewable Energy Effect Matrix represents a potential effect that an offshore renewable energy project may produce, while each column represents a different category of technology (see Appendix C). While the actual effects produced by a particular project are ultimately a result of site specific characteristics and the distribution of resources across a project site, this Offshore Renewable Energy Effect Matrix is presented as a tool for this project to capture the range of potential effects that may result from any offshore renewable energy project developed in the federal waters of the United States. Moreover, the matrix is not meant to be a static or definitive representation of potential effects associated with a technology type, rather it is meant to be updated frequently based on new research or understanding.

The Project Team interpreted the body of literature to summarize the impacts in order to make the matrix broadly applicable. In this way, the matrix highlights the impacts at each scale that are prominent relative to the entire suite of impacts anticipated for any type of ORED.

The magnitude of potential effects (either positive or negative) are represented by color in the matrix, with red representing effects that are considered to generate the greatest change or impact to a resource, assemblage or community; yellow representing effects that are expected to generate a moderate amount of change or impact and; green representing effects that are expected to generate little to no change or impact. Because the current understanding of these potential effects varies based on the relative maturity of the technology type and the available research on their effects, the Offshore Renewable Energy Effect Matrix also incorporates the level of certainty using shading. The most transparent shading represents potential effects in which there is very little certainty, whereas the darkest or most opaque colors represent potential effects in which there is a higher degree of certainty regarding the level of impact or effect. It is important to note, that this matrix does not distinguish between negative impacts or positive benefits, rather it categorizes the general magnitude of an effect. Therefore some of the effects categorized as major may be viewed as beneficial.

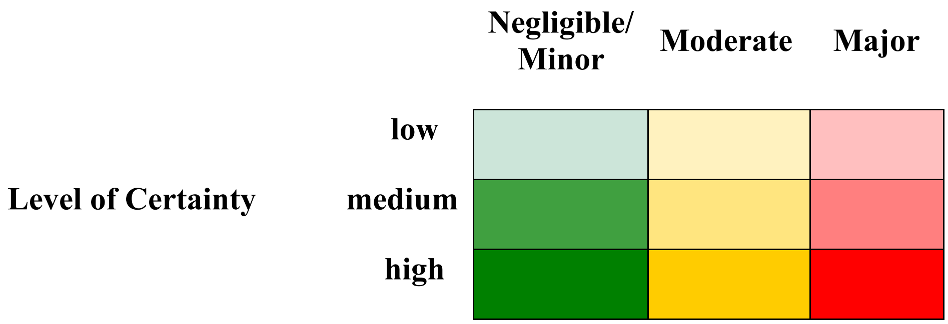
The term “effect” was purposefully used instead of “impact” in the design and discussion of the matrix. While the two terms are often used interchangeably, Boehlert and Gill (2010) explain that “effect” does not indicate a magnitude or significance, whereas “impact” implicitly deals with severity, intensity, or duration of the effect. Furthermore, impact also deals with direction of effect (positive or negative). The distinction between effect and impact is of crucial importance when considering ORED; a number of studies present findings that suggest or show an effect, but further work is usually required for it to be interpreted as an impact.

Determining effects, and distinguishing between effects and impacts, is a complex undertaking. "Biologically significant" impacts may occur at the levels of individual animals, populations, and species. One does not necessarily follow from the other—it is theoretically possible to kill individuals without biologically significant population- or species-level impacts, and, conversely, it could be possible to cause population-level impacts by relatively low-level impacts on individuals (i.e., stress, repeated disturbance). Finally, it makes a very large difference in the scale and duration of a monitoring study whether one is trying to detect short-term effects, including acute mortality of individuals and behavioral changes, or long-term population-level effects such as changes in abundance or demographic characteristics, which can take enormous effort and long times to detect with statistical confidence (Taylor et al., 2007; Thomsen et al. 2011). Because to date, changes have not been observed at the population scale for species potentially affected by ORED, this document discusses changes caused by ORED as effects rather than impacts.

The definitions used for the level of effect and certainty are provided below. Compared to the definitions used in the PEIS which capture only negative impacts, the definitions below capture both positive and negative effects of ORED.

Legend

Level of Effect



Level of Effect	**Definition**
Negligible	• No measurable effect.
Minor	• Should not influence or have only small effects on the affected resource, activity, or community.
Moderate	• Effects could moderately influence the resource, activity, or community, generally or for particular species.
Major	• Effects could significantly influence the resource, activity, or community, generally or for particular species.

Level of Certainty	**Definition**
Low	• Limited to no documentation or anecdotal evidence available
Medium	• Some documentation or anecdotal evidence available; no clear consensus among experts or within literature
High	•Well documented; consensus among experts and within the literature

Potential effects for each scale (Scale 1, 2, and 3) were examined individually with a separate Offshore Renewable Energy Effect Matrix. All three matrices are available in Appendix C in their entirety. Blank cells within the matrix represent no effect.

The general categories of potential effects used in the Offshore Renewable Energy Effect Matrix were based off categories used by Boehlert and Gill (2010) and include:

1. Physical Effects: potential effects caused by the physical presence of an OWE or MHK device or facility, or associated underwater cables. For example, changes in currents, waves, seabed morphology or sediment transport; physical disturbance created during the installation of devices; displacement or attraction to the physical structure; and habitat conversion, including reef effects.
2. Dynamic Effects: potential effects caused by the moving parts of OWE or MHK devices. For example, blade strikes (above and below water), collisions with installation or service vessels, pressure or velocity gradients, or rotor wake around a device.
3. Chemical Effects: potential effects caused by chemicals used to coat or operate ORED. This category also includes the possible release or spill of chemicals associated with vessels installing or servicing the devices.
4. Acoustic Effects: potential effects caused by noise produced during the pre-construction, construction, operation, or decommissioning of a ORED and their associated infrastructure,
5. Electromagnetic Field (EMF) Effects: potential effects caused by the low-frequency electromagnetic fields associated with the transmission of energy produced by ORED.
6. Energy Removal Effects: potential effects caused by localized changes in water movement energy and turbulence around a device or facility.

Section 7.2 summarizes the findings of the Offshore Renewable Energy Effect Matrix.

7.2. Results of the Matrix

7.2.1. Effects on Benthic Habitat and Resources

For the purposes of this project benthic habitat and resources are defined as the abiotic and biotic components of the benthic environment. Construction, operation and decommissioning of structures on the seafloor will affect both abiotic (non-living) and biotic (living) elements. In addition, effects are expected at very local (i.e., species-level) and very broad (i.e., geomorphological) scales. Examples of potential abiotic effects include changes to seabed morphology, scour, and increased suspended sediments. These changes can translate to either losses or gains in benthic diversity and abundance, or shifts in benthic community composition.

The potential effects to benthic animals evaluated in the matrix consider primarily effects to macrofauna (e.g., body size of at least 0.5 mm). The matrix does not refer to direct impacts on microbial communities or demersal fish. In cases where a benthic organism has commercial importance (i.e., a fishery exists), impacts to these species are covered under the "Fish" or "Fisheries" sections.

In general, most of our knowledge about impact of ORED comes from monitoring of OWE farms in Europe; therefore, the certainty of impacts is usually higher for all OWE technology types than for MHK. To date, there are few experimental examinations (i.e., with causal implications) of any individual impacts of offshore renewable energy development on benthic habitat and resources at scales relevant to managers. Most monitoring programs are only capable of detecting "statistically significant" changes to abiotic and biotic metrics in a cumulative manner (e.g., changes to median grain size, species diversity; no definite causal factor is implicated). During the completion of the matrix, the Project Team did not judge whether or not these statistically significant changes translated to ecological significance. In addition, effects on benthic habitat and resources that occur as a result of effects on other resources in the ecosystem (i.e., indirect impacts) are not listed within the matrix.

A brief description of the types of potential effects to benthic habitat and resources is provided below followed by a summary of the results of the Offshore Renewable Energy Effect Matrix.

Changes to currents and waves

The introduction of a number of OWE or MHK devices into the water column may result in changes to the wave field as a result of diffraction or wake effects around a device or an ORED (ABP Marine Environmental Research Ltd 2002; Cooper and Beiboer, 2002; CEFAS 2005; Rees et al. 2006; Bergman et al. 2008; Lambkin et al. 2009; Polagye et al. 2011).

Physical Disturbance and Smothering

Physical disturbance caused by the installation of foundations or underwater transmission cables may result in increased turbidity in the water column and the smothering of some benthic organisms as suspended sediments resettle onto the seafloor (Meibner and Sordyl, 2006; MMS, 2007; BERR 2008b; OSPAR 2008; Walker et al. 2009). The magnitude of the habitat disturbance effects depends on the duration and intensity of the disturbance, and on the resilience of species living within the sediment (Gill 2005; Johnson et al. 2008). Effects to the benthic community around Danish OWE facilities found disturbance from turbine installation was limited primarily to the area immediately surrounding the pile driving activity and the effects of sediment displacement from cable laying found macro algae and benthic infauna were still recovering two years after the activity had ceased (DONG Energy et al. 2006).

Scour

The turbine foundations may increase turbulence and disrupt flow around the structures, potentially causing local erosion around the structures, or "scour". Scour often results in the erosion of the sediments supporting the structure as they are transported elsewhere, forming a hole at the base (DECC, 2008; MMS 2007).

Reef Effects

OWE or MHK structures may serve as artificial reefs by providing surfaces for non-mobile species to grow on and shelter for small fish (Dempster and Taquet 2004; DONG Energy et al. 2006; Petersen and Malm 2006; Wilhelmsson et al. 2006; BERR 2008b; Bouma and Lengkeek 2009; Langhammer and Wilhelmsson 2009). Man-made structures in the marine environment are usually rapidly colonized, increasing the heterogeneity of the habitat (Linley et al. 2007) and may create new pathways for nutrients to be moved from the water column to the benthos (Gill and Kimber 2005).

The reef effects caused by new structures within the water column may also make the area more susceptible to invasion by non-native species (Petersen and Malm 2006; DONG Energy and Vattenfall 2006).

Sediment Temperature

Sediment temperatures may increase around the surface area of buried cables, causing thermal stress to benthic species (Walker et al. 2009).

Chemical Effects

OWE and MHK facilities may contain several types of hazardous toxicants including hydraulic and dielectric fluids (especially in offshore substations), anti-fouling paints and coatings, and other lubricants (MMS 2007; Boehlert and Gill, 2010; Polagye et al. 2010). Incidental release of these chemicals could cause some minor effects to marine organisms, but larger spills could cause major impacts (Polagye et al. 2010; Grecian et al. 2010). Additionally, vessels associated with the construction, operation or decommissioning of ORED could potentially release oil or other chemicals accidentally as the result of a vessel colliding with an OWE or MHK structure or a vessel-vessel accident (MMS, 2007; Johnson et al. 2008; Grecian et al. 2010). Accidental spills are expected to be relatively rare occurrences.

ORED structures may be coated regularly in antifouling paints, such as copper-based antifouling coats similar to the bottom paint of boats that can affect marine organisms (Katranitsas et al. 2003). These anti-fouling paints are important source of chemical contamination in some marine waters (Ranke 2002). This paint may need to be physically removed annually, typically with a high-powered water jet, which can be a pollution issue (Champ 2003, Boehlert et al. 2008, Turner et al. 2009). After cleaning, the paint that has flaked off could be ingested by filter-feeders (e.g., mussels) that in turn could be consumed by other species (Turner et al. 2009).

Water quality may also be affected during the installation of underwater transmission cables by re-suspending pollutants present in the bottom sediments along the coast (OSPAR 2006; MMS 2007; Hooker et al. 2008). However, avoidance of contaminated areas during siting will minimize this effect.

Acoustic

Underwater noise may be generated during all stages of an ORED. It is not understood whether the noise generated in the construction, operation, and decommissioning of an OWE or MHK device or facility would have an effect on benthic species (Boehlert and Gill, 2010). Few marine invertebrates have the sensory organs to perceive sound pressure. However, if there is any effect to these species, it is likely to be much less than any potential effects to fish or marine mammals (Meibner and Sordyl 2006; Linley et al. 2007).

EMF

While EMF is a concern for many marine species (e.g., fish, sharks and rays), the effects on benthic invertebrates are not well known (BERR 2008a; OSPAR 2009). A variety of crustacean species has demonstrated magnetic sensitivity and could be affected by EMF (ICES 2003; Normandeau et al., 2011).

Scale 1

The prominent impacts at this scale include reef effects (e.g., Bouma and Lengkeek 2009) and release of chemicals/large spills (Grassle et al. 1981). The certainty level of reef effects is higher for OWE because reef effects have been studied at more of these facilities than for other technology types (see Table 3). Demonstration scale projects will likely impact a small physical area of seafloor relative to the size of habitats and habitat features, so the impacts from physical disturbance are expected to be minor (Walker et al. 2009). Although this same argument may be used for changes to currents and wave regime, these impacts have been less well studied and so have a lower certainty level. Although the impacts related to acoustics and EMF are very uncertain, they are anticipated to be minor (Meibner and Sordyl 2006).

Scale 2

There are no studies of benthic ecosystems within large (100 devices) renewable energy developments. For these large-scale facilities, the prominent impacts are expected to be due to scour around device foundations, reef effects, and the potential release of chemicals/large spills (see Table 4). The chance of significant impacts from scour to both the abiotic and biotic elements of the environment is high (ABPmer Ltd. et al. 2010). Whereas the chance of chemical spills is relatively small, the scale is large enough that the impacts would be major. Since construction of 100 devices would introduce a significant amount of new hard structures (habitat), the reef effects are potentially high but uncertain since no studies have been conducted at this scale. Impacts related to turbidity and sediment re-suspension will be greater for devices using gravity foundations and/or bottom-mounts at Scale 2. The energy dissipation associated with current and wave devices could constitute a significant and major impact at this scale, but uncertainty is very high (Polagye et al. 2011).

Scale 3

As for Scale 2, there are no studies of benthic ecosystems in a region with multiple large-scale facilities. All of the impacts have very low certainty (see Table 5). The potential major impacts are similar as for Scale 2, although stressors that are not important at smaller scales could become important at Scale 3, and/or new impacts that have not yet been anticipated could occur at this large scale. Changes to energy regime, and increases in turbidity, sediment re-suspension, plus chemical spills and reef effects could be major.

Table 3

Offshore Renewable Energy Effect Matrix- Scale 1, Benthic Habitat and Resources

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids;Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decomissioning													
	EMF	EMF from power cable													

Table 4

Offshore Renewable Energy Effect Matrix- Scale 2, Benthic Habitat and Resources

Scale 2- Single Commercial Scale Facility			**Technology Type**												
			Wind				**Currents**				**Waves**				
			Foundation				***Turbine Type***				***Device Type***				
							Open Rotor		**Shrouded**						
		Potential Effect	**Monopile**	**Gravity**	**Tripod/lattice**	**Floating Mooring**	**Bottom Mounted**	**Floating Mooring**	**Bottom Mounted**	**Floating Mooring**	**Point Absorber**	**Wave Attenuator**	**Oscillating Water Column**	**Oscillating Wave Surge Converter**	**Overtopping**
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decommissioning													
	EMF	EMF from power cable													

Table 5

Offshore Renewable Energy Effect Matrix- Scale 3, Benthic Habitat and Resources

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type												
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decommissioning													
	EMF	EMF from power cable													

7.2.2. Effects on Fish and Fisheries

The potential effects to fish and fisheries are presented together due to the interrelationship between the two. It is important to note that potential effects to fish and fisheries will vary seasonally and based on the location of a project. The results of the Offshore Renewable Energy Effect Matrix assume that the most sensitive areas for fish species (e.g. spawning grounds, important migratory corridors, etc.) are avoided when siting ORED. A summary of the potential effects considered in the matrix are provided below.

Disturbance

Fish species may be temporarily disturbed by OWE or MHK installation or decommissioning activities, as well as the installation or removal of an underwater transmission cable (Meibner and Sordyl, 2006; MMS, 2007; BERR 2008b; OSPAR 2008; Walker et al. 2009). The expected effects are a local loss of sedentary fauna living in the substrate, with mobile bottom-dwellers being displaced from the area (Gill 2005). During the construction and decommissioning phases of a project, the eggs and larvae of many fish species may be vulnerable to being buried or removed (Gill 2005; Johnson et al. 2008).

Collision/Blade Strikes

The possibility of blade strike in tidal energy devices is particularly a concern for fish. It is expected that the likelihood of strike would be far lower with a MHK device than for traditional hydroelectric devices on rivers, where fish have little opportunity to avoid the device (Polagye et al. 2010). Avoidance behavior by fish to rotating MHK devices have been demonstrated in current Scale 1 projects which has minimized the risk from blade strikes (Snohomish County Public Utility District 2009; Verdant Power 2010; Zydlewski 2011).

Pressure or Velocity Gradients and Rotor Wake

The potential effects to fish from pressure or velocity gradients or rotor wake are limited to MHK devices. Polagye et al. 2010 hypothesized that the effects from the wake of MHK rotors were likely to be highly localized to the area surrounding the blades, and therefore will have limited effects to fish. However, due to the lack of publically available data on this potential effect, more research is necessary.

Chemical Effects

Accidental release of toxic substances or debris into the water column by OWE or MHK substations, devices or associated vessels may affect the water quality around an ORED. In addition, the potential effects of anti-fouling coatings and the re-suspension of polluted sediments in coastal areas may affect fish species. For a more detailed description of these types of potential effect see Section 7.2.1.

Noise

Little is understood about the effects of noise on fish. Fish vary greatly in their hearing structures and auditory capabilities, so it is difficult to generalize about the effects of noise generated by ORED construction and operation on fish. There is lack of knowledge about the hearing capacities of most fish species. Certain fish species are thought to be hearing specialists, and may have enhanced hearing sensitivity and bandwidth, while others may be hearing generalists, and may be less sensitive to sound (Popper and Hastings 2009). Similar to marine mammals (see Section 7.2.4), the effect of noise will depend on the overlap between the frequency of the noise and the level of hearing of the species, and whether the sound exceeds the level of ambient noise (Thomsen et al. 2006). The impact of the sound produced will also vary greatly depending upon the environmental setting and conditions at the time and place where the sound is being produced (Popper et al. 2006).

The potential effects of sound from OWE and MHK pre-construction, construction, decommissioning, and operation, on fish can be divided into three general categories:

1. temporary or permanent hearing damage or other physical injury or mortality;
2. behavioral responses; for example, the triggering of alarm reactions, causing fish to flee or interrupting activities necessary for survival (e.g. feeding) and reproduction, and potentially inducing stress in the fish;
3. masking acoustic signals, which may be communication among individuals, or may be information about predators or prey (Thomsen et al. 2006).

It is thought fish will be able to hear the noise generated by wind turbines, although it is not known whether the fish will be disturbed by it or will acclimate to the sound (Wahlberg and Westerberg 2005; Popper and Hastings 2009). A potentially more serious effect is the noise produced by pile driving and cable laying, which produce noise levels that could damage the hearing of some fish species close to the source (Nedwell et al. 2003; Mueller-Blenkle et al. 2010). Thomsen et al. (2006) found that the noise produced by pile driving might be audible to cod and herring at a distance of 80 km from the source, and thus the effects of noise could be significant beyond the immediate vicinity of the construction project. One study of pile driving found fish of several different species were killed within at least 50 m [164 feet] of the pile driving activity; it also found an increase in the number of gulls in the area, indicating additional fish mortality (Caltrans, 2001). Another study found that the noise levels produced by pile driving during wind tower construction and cable-laying could damage the hearing of species within 100m [328 feet] of the source (Nedwell et al. 2003). Nedwell et al. (2003) also calculated that cod would demonstrate significant avoidance reactions up to 5.5 km from the pile driving, although this is difficult to determine with any certainty. Noise produced by wind turbines and other offshore renewable energy devices could also mask communication signals (Thomsen et al. 2006).

The noise created during the construction and decommissioning processes may cause some fish species to leave the area. This avoidance behavior could cause a disruption in feeding, breeding, or other essential activities, and may have significant impacts if fish are removed from a spawning area. Less mobile species are likely to be more susceptible (Gill and Kimber 2005). The effect on fish populations would be greater if they are dispersed during the times of year when they would be naturally congregating for spawning or other purposes (Gill and Kimber 2005).

EMF

While the effects of EMF are poorly understood on all species, it is known that some species of fish, invertebrates, marine mammals, and sea turtles may be sensitive to EMF. Electrosensitive species such as elasmobranchs may be either attracted to or repelled by emitted electric fields. Elasmobranchs and migratory fish are known to be magnetosensitive, but it is not known whether they will be affected by magnetic fields emitted by offshore renewable energy devices (Gill 2005). The induced electrical fields created by the magnetic fields from the cables are within the range of electrical transmissions detectable by sharks and rays (Gill and Kimber 2005). If the electric fields being emitted by the cables approximate the bioelectric fields of some species, there is a possibility that certain electro-sensitive species, particularly elasmobranchs (sharks, skates, and rays) and sturgeon species, will be attracted to the cables, thinking them to be prey. The same species may be repelled by stronger electric fields closer to the cables, depending on the power sent through the cable and the characteristics of the cable itself. Because the cables will be buried in sediment or laid along the bottom, benthic species are most likely to encounter them (Gill and Kimber 2005).

One study on the European eel (*Anguilla anguilla*) found a significant decrease in swimming speed when passing over an AC cable (Westerberg and Lagenfelt 2008). A study of cables at Danish wind farms found some effects on fish behavior from the presence of the cables, but the effects included both avoidance and attraction, and could not be correlated with the strength of the EMFs (DONG Energy et al. 2006). Catch studies on some species of fish (Baltic herring, common eel, Atlantic cod and flounder) at the Nysted wind farm in Denmark found the catches of these species were reduced in the vicinity of the cables, indicating the migration of fish across the cables may be reduced, but not blocked. In a separate study, they also found cod accumulating close to the cables however this was not when the cables were energized so there may be some other stimuli that the fish were responding to such as the physical presence of the cable trench (DONG Energy and Vattenfall 2006).

Habitat Alteration and Reef Effects

Because the placement of OWE or MHK devices and scour protection may increase habitat for benthic species, the structures may have the effect of increasing local food availability, which may bring some fish species into the area. Scour protection and foundation structures may also provide refuge from predation for juvenile fish species or refuge for both large and small fish and other species from fishing pressure (MMS 2007; Wilhelmsson et al. 2010).

A study of OWE facilities in Danish waters found the increased habitat heterogeneity from turbine foundations resulted in an increase of species from adjacent hard surfaces, leading to a local increase in biomass of 50 to 150 times, most of which served as available food for fish and seabirds (DONG Energy et al. 2006). If individual fish are being attracted to the site, but populations are not increasing, this may have impacts on adjacent habitats where the fish would ordinarily be found (Gill 2005).

Ehrich et al. (2006) hypothesize that any effects on fish densities and diversity resulting from newly installed OWE turbines will be restricted to the immediate vicinity of the structures, and will not have wide-reaching effects, unless rare species are directly affected, which could have effects at the population level. The authors also note that in cases where wind turbines are constructed in areas with a sandy bottom, there may be localized removal of species dependent on soft-bottom habitat, favoring species which prefer hard bottoms, as the hard structures serve as habitat for these species. They suggest that the wind farms will also favor large predators, particularly if fishing pressure among the turbines is reduced (Ehrich et al. 2006).

Because some European ORED have been fully or partially closed to fishing activity, the reef effects observed in these facilities may be in part due to decreased fishing disturbances (DONG Energy et al. 2006)

Effects to Fisheries

The ability for commercial or recreational fishermen to catch target fish species may be affected by the presence of and OWE or MHK facility or pre-construction related activities due to changes in fish distribution patterns. Engås et al. (1996) found the average catch rates for cod to decrease by about 50% both in the immediate vicinity of and at a distance from air gun activity. Haddock catches also decreased by similar percentages. Five days after the air gun was used, fish catches had not increased. However, as noted above, air guns are unlikely to be used in the pre-construction siting process. Westerberg (1994, 2000, as reported in Thomsen et al. 2006) found that catches of cod decreased within 100m [328 ft] of a wind turbine while it was operating, likely because of the noise generated by the turbine itself. The study also found higher catches within 100m [328 ft] of the turbines than in the surrounding areas when the turbines were stopped, likely because of the reef effect. However, in a separate study, Wahlberg and Westerberg (2005) estimated that the levels of noise produced by operating OWE turbines (1.5 MW) were only likely to cause avoidance responses by fish closer than 4 m [13 ft] to the turbines and only at high wind speeds (13 m/s [29.1 mph]). They also noted that fish may habituate to the noise created by the wind turbines and disregard the sound. The potential effect of operational noise on fish may vary between projects, as operational noise will varies depending on the turbine size, model, foundation type and speed of rotation.

There is also the potential for secondary effects on fish populations if fishermen are displaced from the wind farm area, and as a result concentrate their efforts elsewhere on vulnerable populations or habitats (BMT Cordah Limited 2003). Likewise, if the wind turbines serve as fish aggregating devices, attracting and concentrating fish from elsewhere, and attracting more commercial and recreational fishing activity to the area to take advantage of the aggregation, it could have the undesired outcome of leaving fish species more vulnerable to overharvesting from more concentrated fishing effort (Whitmarsh et al. 2008).

Offshore renewable energy facilities may have an adverse impact on commercial and recreational fishermen’s access to traditional fishing grounds. The degree of impact varies significantly by facility design, stage of the development process, location in the offshore environment, and type of fishing activity, and may be either temporary or long-term. Fishermen may be displaced from traditional fishing grounds by the structures themselves, regulatory decisions that limit access around the structures or through the facility, or other factors. For example, fishing access around existing OWE facilities in Belgium, Germany, the Netherlands, and the United Kingdom is subject to restrictions imposed by those countries’ respective governments. In Belgium, Germany, and the Netherlands, a 500-meter Safety Zone is established around the entire wind farm, and fishing is prohibited within this area. In the

United Kingdom, a 500-meter [0.3 mi] Safety Zone is established around each individual turbine only during the construction period. During operation, a 50-meter [164 ft] Safety Zone is established around each individual turbine. These restrictions are primarily instituted for safety reasons and are similar to those applied to offshore oil and gas rigs in these same countries (except for Belgium, where there are no rigs). These findings were confirmed through responses to informal questionnaires completed by the Center for Environment, Fisheries, and Aquaculture Science in the UK; the German Maritime and Hydrographic Agency; and the Belgian and Dutch delegations to the OSPAR and London Convention Scientific Group, March 12, 2010 as part of the Ocean Special Area Management Plan (RI CRMC 2011).

Alternatively, the some argue that areas around OWE or MHK devices closed to fishing activity may lead to increases in fish abundance that may spill over to nearby areas and enhance fishing activity (Whilhelmsson et al. 2010).

ORED may present a navigational hazard for fishing and other vessels, and there is some risk of collision with turbines, or with service vessels. Damage to or loss of fishing gear is also a concern related to ORED (Mackinson et al. 2006). Power cables and bottom fishing gear present mutual possibilities for damage, and may endanger the safety of fishing vessels. Burying cables between the turbines, as well as from the wind farm to shore, will mitigate some of this problem. However, even if cables are buried, there is a potential for them to become uncovered through sea bed movement, putting a trawled net and perhaps the fishing vessel in danger of hang ups (Rodmell and Johnson 2005).

Scale 1:

At the demonstration scale (Scale 1), there are likely to be some disturbance effects from installation and presence of the device, and from the installation of the power cable, as well as the noise generated by these activities (see Table 6). These effects would likely be minor, because of the small scale of the project, and the disturbance and noise caused by construction of the device will be short lived. For tidal power devices, there could be effects from the rotor itself, including fish strikes in the blade, and effects due to changes in pressure and velocity gradients around the rotor. While these effects are also likely to be minor at this scale, there is considerable uncertainty around the likelihood of these effects (Polagye et al. 2010). Reef effects, particularly biofouling and a resulting aggregation of fish seeking food or shelter, are likely to occur at any scale, as a new type of surface is being placed in the water. This is likely to be minor at a demonstration scale, as the total surface area is small, and increase as the surface area of new devices place in the water increases.

Effects to fishing activity include a loss of access to grounds during construction and operation. Loss of access to grounds during construction is ranked as minor, because of a limited temporal scale of construction. Loss of access during operation is ranked as minor for fixed gear (e.g. gillnets, lobster pots, etc.) and recreational fishermen, who will likely be able to continue fishing around the devices, but is ranked as moderate for mobile gear fishermen (e.g. trawling, dredging), who will not be able to continue fishing around the devices and will be displaced from the area for the duration of the project. Reef effects are addressed separately in the fish and fisheries sections; reef effects are likely to affect fishing activity, particularly recreational fishing, if fish and thus fishermen aggregate around the devices.

Scale 2:

At Scale 2, with an entire farm of devices, the disturbance effects are likely to increase. Most of these effects are likely to be minor or negligible, with the exception of installation (see Table 7). The installation of a large scale facility is likely to result in at least a moderate level of physical disturbance to the bottom and the water column, although the level of disturbance will vary depending on whether the devices are permanently fixed to the bottom or only moored. The potential effects caused by the movement of tidal turbines underwater increase as the number of turbines increase, and particularly the potential for blade strikes and for effects caused by pressure gradients, but there is a great deal of uncertainty around these effects, as they are not well understood. The potential for chemical effects resulting from a leak or an accident increases as well, as the number of devices and the number of vessels traveling through the area for construction or maintenance increases, although the scale of the effect remains the same.

In terms of acoustic effects, operational noise is ranked as having a moderate effect with a moderate level of uncertainty for all device types; all devices will create some noise while in operation, whether from gear movements, mooring chains, or other moving parts. The potential effect this additional noise could have, if any, on fish is not well understood (Wahlberg and Westerberg 2005), but will likely be a function of the number of devices (Gill 2005) among other factors. There are also likely to be additional moderate acoustic effects from pile driving activity, including sound levels high enough to affect the hearing of some fish and to cause fish to leave the area (Nedwell et al. 2003). There may also be moderate effects from pre-construction surveying and pile cutting for device removal that would be required for those devices installed by pile driving. The potential for effects from EMF is ranked as moderate for this scale, as the number of cables increases, but with a high level of uncertainty. Effects of EMF may include attraction or displacement, and will be species-specific (Gill 2005). There is also an increase in the likelihood of community-level impacts, including a shift in community composition resulting from changes to habitat, although this will vary depending on the species and the susceptibility and resilience of the community as a whole (Gill 2005). Similarly, the potential for reef effects increases significantly as more devices are placed in the water. The potential for reef effects on devices with more surface area, including wind turbines and tidal turbines, is ranked as major.

Effects to fishing activity also increase at this scale. Effects to catchability increase with the level of disturbance to fish created at the construction and operation stages, but there is much uncertainty, as these are secondary effects. The loss of access to grounds will be a major effect during construction for all fisheries, and will continue to be a major effect to mobile gear commercial fisheries during the operational phase. Fixed gear fisheries (lobster and fish pots, gillnets), and recreational fisheries may continue to operate around the devices during operation; the effect of loss of access is moderate. The potential for changes in species distribution, and the resulting effect on fisheries, is also ranked as moderate, but with high uncertainty. The potential for reef effects to affect fishermen is ranked as moderate, as is the potential for damaged or lost gear.

Scale 3:

At Scale 3, multiple large facilities in a region, the uncertainty level for all effects is significantly increased, as there is no experience and thus no data at this level (see Table 8). Specific concerns for fish could be disturbance to fish, particularly from installation, and then particularly of any device that is permanently affixed to the seafloor (all but the floating devices). Physical disturbance could include increased turbidity and sedimentation, which may affect fish, as well as larvae or fish prey species. The potential for blade strikes, while not well understood, will increase as the number of turbines in the water increases. Noise related to pile driving, seismic surveying, and pile removing also has the potential to have a major effect at this scale for technologies where these effects are relevant. Aggregation due to reef effects could be major for all technologies at this scale, and community composition could also be affected to a large degree; again, these potential effects are not understood well enough to accurately predict their likelihood.

Effects to fishing activity will scale up with multiple OWE or MHK facilities, but as many of these are secondary or tertiary effects, predicting their occurrence becomes increasingly speculative. Loss of access to grounds during construction, and during operation for vessels using mobile fishing gear, will likely be a major effect at this scale.

Table 6

Offshore Renewable Energy Effect Matrix- Scale 1, Fish and Fisheries

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				Turbine Type				Device Type				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Fish	Physical	Disturbance from installation device													
		Disturbance from removal of device													
		Disturbance from installation of power cable													
		Disturbance removal of power cable													
	Dynamic	Collision/Blade Strike													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids during operation													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (gears, mooring chains, etc.)													
		Noise from pre-construction seismic surveying													
		Noise from vessels conducting project maintenance/monitoring													
		Noise from pile driving													
		Noise from vessel traffic during installation													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
		Noise from vessel traffic during removal													
	EMF	EMF from power cable													
	Community level impacts	Habitat alteration/community composition													
		Reef effects (aggregation)													
Fisheries		Decreased Catchability during construction													
		Decreased Catchability during operation													
		Loss of access to grounds during construction													
		Loss of access to grounds during operation - mobile fishing gear													
		Loss of access to grounds during operation - fixed and recreational fishing gear													
		Changes in species distribution													
		Reef effects (aggregation)													
		Damage/lost gear													

Table 7

Offshore Renewable Energy Effect Matrix- Scale 2, Fish and Fisheries

Scale 2- Single Commercial Scale Facility			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Fish	Physical	Disturbance from installation device													
		Disturbance from removal of device													
		Disturbance from installation of power cable													
		Disturbance removal of power cable													
	Dynamic	Collision/Blade Strike													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids during operations													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (gears, mooring chains, etc.)													
		Noise from pre-construction seismic surveying													
		Noise from pile driving													
		Noise from vessel traffic during installation													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
		Noise from vessel traffic during removal													
	EMF	EMF from power cable													
	Community level impacts	Habitat alteration/community composition													
		Reef effects (aggregation)													
Fisheries		Decreased Catchability during construction													
		Decreased Catchability during operation													
		Loss of access to grounds during construction													
		Loss of access to grounds during operation - mobile gear fisheries													
		Loss of access to grounds during operation - fixed and recreational fisheries													
		Changes in species distribution													
		Reef effects (aggregation)													
		Damage/lost gear													

Table 8

Offshore Renewable Energy Effect Matrix- Scale 3, Fish and Fisheries

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type															
			Wind				Currents				Waves							
			Foundation				Turbine Type				Device Type							
							Open Rotor		Shrouded									
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping			
Fish	Physical	Disturbance from installation device																
		Disturbance from removal of device																
		Disturbance from installation of power cable																
		Disturbance removal of power cable																
	Dynamic	Collision/Blade Strike																
		Pressure gradients around rotor																
		Velocity gradients around rotor																
		Rotor wake																
	Chemical	Diffusion/flaking marine coating																
		Leakage lubricants/fluids during operations																
		Large spills or accidents																
		Chemicals discharged during installation or removal																
		Resuspension of pollutants in sediments																
	Acoustic	Operational noise (gears, mooring chains, etc.)																
		Noise from pre-construction seismic surveying																
		Noise from pile driving																
		Noise from vessel traffic during installation																
		Noise from directional drilling for power cable																
		Noise from pile cutting during device removal																
		Noise from vessel traffic during removal																
	EMF	EMF from power cable																
	Community level impacts	Habitat alteration/community composition																
		Reef effects (aggregation)																
Fisheries		Decreased Catchability during construction																
		Decreased Catchability during operation																
		Loss of access to grounds during construction																
		Loss of access to grounds during operation - mobile gear fisheries																
		Loss of access to grounds during operation - fixed and recreational fisheries																
		Changes in species distribution																
		Reef effects (aggregation)																
		Damage/lost gear																

7.2.3 Effects on Avian and Bat Species

At the present time, many of the documented environmental impacts on birds from ORED are based on studies of OWE facilities in Europe (Percival 2001, 2003; Drewitt and Langston 2006; Fox et al. 2006). There is higher uncertainty regarding the effects of MHK technologies on birds because only several pilot projects have been constructed and there have been few published studies (Leijon et al. 2003, Henfridsson et al. 2007, Grecian et al. 2010, Langton et al. 2011). Few studies have been conducted related to potential effects to bats from ORED, therefore, there is far less certainty surrounding these effects. A brief description of the potential effects considered in the Offshore Renewable Energy Effect Matrix are provided below, as well as a brief summary of the findings of the matrix.

Displacement/Avoidance

Previous monitoring efforts at offshore wind facilities in Europe have documented that above-water physical structures (e.g., tower and turbine) can lead to an avoidance response by certain species of birds (e.g., loons, terns, seaducks, and gannets; Petersen 2005), which may affect birds by increasing flight distances and energy consumption (i) during long-distance migratory flights, and (ii) during local feeding flights (Desholm and Kahlert 2005; Fox et al. 2006; Desholm 2009; Masden et al. 2010). Based on diving depths of seabirds that occur in nearshore habitats where these technologies will be used, displacement will likely be greatest among surface (e.g., cormorants) and plunge diving species (e.g., gannets; Langton et al. 2011). For long-distance migrants, Masden et al. (2009) showed that energetic costs to migratory common eider were relatively trivial; 500 m displacement in a 1400 km migration. However, the energetic costs could be substantial for locally feeding birds that are displaced regularly (e.g., terns provisioning young at nests or wintering seaducks that feed and roost in different areas). In addition, as the number of projects increase, the cumulative impacts of this avoidance behavior could be significant.

Furthermore, the presence of physical structures has been associated with the absence (e.g. red-throated loons) and reduced feeding densities (e.g. long-tailed ducks) within OWE projects post construction compared to areas outside (Petersen et al. 2006). In the latter case, the term “effective” habitat loss has been applied because avoidance of the ORED could lead to avoidance of intact food resources due to visual disturbance, which could also result in reduced energy intake rates to displaced individuals and increased energy expenditure (Fox et al. 2006). However, some avian species may increase their use of the area near OREDs because the infrastructure provides some species with perch sites (e.g., gulls and cormorants). Researchers working around offshore oil platforms have documented increases in avian densities near these static structures (Tasker et al. 1986, Baird 1990, Wiese and Montevecchi 2000, Weise et al. 2001).

Although many species of marine birds avoid OWE project sites immediately following construction (Garthe and Hüppop 2004, Petersen 2005), there is some evidence that some species may habituate to the physical presence of offshore wind facilities after a number of years following construction (Langston and Pullian 2003). This result suggests that displacement effects from the physical presence of ORED devices may not persist for some species and that birds may habituate to structures above and below the surface of the water (Drewitt and Langston 2006).

It is unclear whether MHK structures below the surface of the water will cause the same levels of avian displacement as wind turbines (Grecian et al. 2010). Tidal stream and wave technologies have submerged, large static (chains and moorings) and dynamic (turbine blades) components, but few observational data exist to assess avian attraction or avoidance of these developing technologies (Langton et al. 2011).

Lastly, vessel traffic associated with all phases of ORED projects may also disturb and potentially displace birds from an area. For example, Kaiser et al. (2006) found common scoters (*Melanitta nigra*) avoided areas with high prey density if there were high levels of shipping activity in the area.

Attraction

There is the possibility that some species could be attracted to offshore superstructures, although data and quantitative studies are limited. The lower portions of offshore wind turbines can provide limited perching opportunities for some species of birds (A. Fox, pers. comm.), which may lead to changes in the spatial distribution of birds in the ORED area (Wiese et al. 2001). Birds are known to perch on wind turbines onshore, although they rarely perching on active turbines (Smallwood et al. 2009). Also, migrating landbirds could attempt to perch on ORED structures during long migratory flights during certain weather conditions, based on observations from oil and gas platforms in the Gulf of Mexico (Wiese et al. 2010) and observations of birds landing on masts, transformer stations, and other structures associated with offshore wind facilities (A. Fox., pers. comm.)

Lighting

One of the most important factors affecting collision risk at tall structures is lighting, which is required as warning lights for aircraft and vessels (Drewitt and Langston 2008). Birds can be attracted to and disoriented by anthropogenic lights, often when weather conditions are either foggy or overcast with drizzle (Gauthreaux and Belser 2006, Longcore et al. 2008). Available evidence suggests that intermittent lighting reduces collision probabilities for migratory birds, thus continuous red or white lights should not be used on ORED (Gauthreaux and Belser 2006, Longcore et al. 2008, Gehring 2009).

Collision

The potential collision risk of an ORED on birds differs between parts of structures above the ocean surface (e.g., OWE nacelle and tower; Drewitt and Langston 2006, Longcore et al. 2008) or below the surface (e.g. MHK rotor; Pelc and Fujita 2002, Wilson et al. 2006; Langhamer et al. 2009, Grecian et al. 2010, Langton et al. 2011).

Although OWE structures are large and provide a potential collision hazard, available evidence has shown that birds readily avoid offshore wind facilities by altering flight paths (Desholm and Kalhert 2005). Much less is known about avian behavioral responses to MHK power generation devices mounted on the seafloor, although it is assumed that these devices will probably have a low collision risk for most species of birds (Pelc and Fujita 2002; Wilson et al. 2006; Grecian et al. 2010; Langton et al. 2011). Structure size and dimensions of ORED will affect collision risk for birds, particularly under poor visibility conditions for structures above the ocean surface (Winkelman 1992, Ogden 1996, Crawford and Engstron 2001, Chamberlain et al. 2006, Hötker et al. 2006, Drewitt and Langston 2008, Desholm 2009).

Pressure and Velocity Gradients

No studies to date have been conducted on the effects of ORED pressure and velocity gradients on birds. However, injuries and fatalities related to pressure and velocity gradients around onshore wind turbines have been studied in bats (Baerwald et al. 2008). More research is needed on this potential effect. It is assumed that pressure and velocity gradients around the rotor of tidal ORED devices will not seriously injure or kill birds, but this has not been extensively studied.

Acoustics

Little is known about avian sensitivity to noise emitted by OWE and their ability to habituate to the noise (Gill 2005). However, anthropogenic noise on land has been shown to affect the spatial distribution and abundance of birds (Forman and Deblinger 2000; Fernandez-Juricic 2001). In addition, little is known about the impact of underwater noise on birds. However, some experimental evidence suggests that underwater noise may affect predation rates on mollusks by waterfowl (Ross et al. 2001).

Energy Effects

ORED could have indirect impacts on birds that forage and roost in marine waters (Gill 2005, Inger et al. 2009, Grecian et al. 2010). MHK devices could alter local oceanographic processes that could affect foraging opportunities for marine birds. However, little is known about direct physical and indirect environmental effects of changes in energy around these machines. Grecian et al. (2010) speculated that for wave-powered facilities, reductions in wave energy could affect mixing of the upper layers of the ocean which in turn could have a negative effect on marine life and fisheries (Pelc and Fujita 2002; Gill 2005; Boehlert and Gill, 2010and may result in a reduction in prey availability for birds. Alternatively, accumulated sediments resulting from changes to localized currents may increase food availability for birds (Grecian et al. 2010). In either case, the indirect energy effects of MHK on birds will likely be minimal (Pelc and Fujita 2002).

Bats

The potential impacts of OREDs on bat populations are just beginning to be understood. Based on the physical structure of most MHK technologies, those technologies that have a profile just on the surface (e.g., floating technologies) or subsurface (e.g. bottom mounted facilities) will have no impact on bat populations because over water bats are only in flight, thus there is little potential for bat populations to be impacted.

However, there is the potential for OWE facilities to have an impact on some bat populations, but the level of impact is uncertain (reviewed by Barclay et al. 2007, Kunz et al. 2007, NRC 2007, Arnett et al. 2008). There have been high fatality rates of bats documented at some land-based wind facilities in eastern North America, with fatality rates ranging from 15 bats/MW/year to 41 bats/MW/year (reviewed in Kunz et al. 2007, Arnett et al. 2008). Species most vulnerable to collisions are migratory species that are most likely to venture out to sea during long-distance flights. In the northeastern United States, this includes three species of so called "tree bats" that roost solitarily and winter in the southern US including red bat (*Lasiurus borealis*), silver-haired bat (*Lasionycterus noctivagans*), and hoary bat (*Lasiurus cinereus*) (Cryan and Brown 2007, Arnett et al. 2008, von Oettingen 2011).

Offshore surveys are just being initiated for bats, but preliminary surveys suggest that some species, in particular red bat, are likely to be found offshore during fall migration (Cryan and Brown 2007, Johnson et al. 2010). There is a great deal of concern for bats in North America due to massive mortality events caused by the psychro-philic fungus (*Geomyces destructans*) leading to white-nosed syndrome that occurs in cave-dwelling bats that roost communally (Blehert et al. 2009).

Scale 1

Because most research investigating bird-ORED interactions has taken place at the scale of a single commercial facility (Scale 2), more is known about habitat displacement and collision risk at Scale 2. Less is known about the impact of individual devices at the demonstration scale. It is assumed that all effects at this scale will be either minor or negligible. Those effects with the greatest level of certainty are those related to wind turbines, as these effects are better documented than those related to MHK devices. Displacement, collision, and pressure or velocity gradients can affect avian species with even a single turbine (see Table 9).

Scale 2

The one major potential effect to avian species at this scale is the potential displacement from an area due to the physical presence of multiple large structures above the water surface (e.g., offshore wind turbines; see Table 10). Previous monitoring efforts at commercial OWE facilities of this scale in Europe have documented an avoidance response by certain species of birds (e.g., loons, terns, seaducks, and gannets; Garthe and Hüppop 2004, Petersen 2005; Maclean et al. 2006, 2007), which may affect birds during migration and feeding flights by increasing flight distances and energy consumption (Desholm and Kahlert 2005; Fox et al. 2006; Masden et al. 2009, 2010).

The potential attraction to OWE facilities due to reef effects and increased prey availability caused by structures below the water surface have been documented in some avian species (e.g., gulls; Garthe and Hüppop, 2004; Petersen, 2005). In addition, researchers working around offshore oil platforms have documented increases in avian densities near these static structures (Tasker et al. 1986, Baird 1990, Wiese and Montevecchi 2000, Weise et al. 2001). As a result, the potential for attraction caused by structures below the surface was categorized in the matrix as moderate for OWE technologies.

In addition, the potential for collisions, pressure gradient effects, and the risk of accidental spills or other chemical effects have been categorized as moderate based on available research.

Scale 3

Similar to Scale 2, the major potential effect to avian species from multiple projects within a region are the potential effects of avoidance or displacement. However, there is much less certainty at this scale.

Table 9

Offshore Renewable Energy Impact Matrix- Scale 1, Avian Effects

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				Turbine Type				Device Type				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation, maintenance and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													

Table 10

Offshore Renewable Energy Impact Matrix- Scale 2, Avian Effects

Scale 2- Single Commercial Scale Facility			Technology Type												
			Wind				Currents				Waves				
			Foundation				Turbine Type				Device Type				
							Open Rotor		Shrouded						
Potential Effect			Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradient around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation, maintenance and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													

Table 11

Offshore Renewable Energy Impact Matrix- Scale 3, Avian Effects

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type														
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradient around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation, maintenance and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													

7.2.4. Effects on Marine Mammals and Sea Turtles

Marine mammals (whales, dolphins, porpoises, seals, sea lions, fur seals, walruses, sea otters, polar bears, and manatees) and sea turtles all receive special protections under U.S. federal law. All marine mammal species are protected from harm (including mortality, injury, and disturbance) by the Marine Mammal Protection Act (MMPA). Some species or populations that have been listed as Endangered or Threatened under the Endangered Species Act (ESA) have an additional layer of federal protection. There is no equivalent federal law specifically protecting sea turtles, however all of the species occurring in or near U.S. waters are listed under the ESA and therefore protected.

While European OWE facilities have conducted studies on the potential effects to marine mammal species present at their project sites, those efforts have been primarily focused on effects to seals and porpoises. The effects to whales and other marine mammal species, as well as sea turtles from ORED have been less studied.

Acoustic effects are of particular concern for marine mammals, many of which are known to have highly sensitive hearing. Dynamic effects, particularly the potential for vessel strikes, are also important for marine mammals and sea turtles.

The other three classes of effects—physical, chemical, and EMF—appear to be of substantially lower concern than acoustic and dynamic effects. EMF effects on marine mammals and turtles are poorly understood. Some impacts would change significantly depending on specific locations and affected species. For example, developments or construction onshore or very near shore in areas of sea turtle nesting beaches or seal pupping sites could have very large impacts on those populations.

Reef Effects

Reef effects caused by OWE or MHK facilities may increase the biomass locally, and attract fish and marine mammals as their predators (Wilhelmsson et al. 2006; OSPAR 2006; NOAA 2009). For example, the offshore wind farm foundations at Horns Rev and Nysted have been readily colonized with epifouling communities, causing a local increase in biodiversity compared to amounts recorded prior to construction (DONG Energy et al. 2006; Bioconsult A/S 2003; Energi E2 A/S 2004). However, no evidence has been found to date to suggest that these reef effects enhance or alter the prey availability of marine mammal species in the area.

Entanglement with Mooring Lines or Cables

The PEIS, Polagye et al. (2010) and Boehlert et al. (2007) suggested one potential effect to marine mammals is possible entanglement with slack mooring lines associated with floating ORED. However, to date there has been no research conducted on this potential effect.

Collision/Blade Strikes

Given the small number of deployments of MHK devices and paucity of published information on possible effects it is difficult to draw conclusions on the potential effects to marine mammals and sea turtles (Wilson et al. 2007). The Sea-Gen Tidal Project in Ireland has conducted common seal monitoring at their demonstration project and to date has not recorded any collisions or blade strikes. However, the project currently shuts down when a seal is detected within 50 meters (Fortune and Ainsworth 2011). Whilst it is possible that MHK blades may turn slow enough that they can be easily avoided by large, mobile animals, empirical evidence is needed to determine the level of effect. The PEIS noted that collision may be of concern for sea turtle hatchlings and small juveniles.

Vessel Strikes

Mortality or injury from collisions with vessels is a serious concern for marine mammals and sea turtles (NRC 1990; Waring et al. 2009; Allen and Angliss 2010; Carretta et al. 2010). Some species, notably North Atlantic right whales, appear to be particularly susceptible to ship collisions. Nevertheless, even with right whales, collisions are rare events and most often associated with relatively large vessels travelling at higher speeds. For right whales, which are an Endangered Species with a very small population, ship collisions may be a serious impact. Vessel collisions have also been implicated as a significant source of anthropogenic mortality for sea turtles (NRC, 1990). Any increase in vessel traffic associated with any phase of ORED could increase the risk of collisions. However for most species, a rare mortality or injury to a single individual from a vessel collision is not likely to be a serious impact at the population level. Finally, collision risk can be mitigated relatively easily by requiring project vessels to transit at speeds of 10 knots or less (MMS 2007).

Chemical Effects

Accidental release of toxic substances or debris into the water column by OWE or MHK devices or associated vessels may affect the water quality around an ORED. In addition, the potential effects of anti-fouling coatings and the re-suspension of polluted sediments in coastal areas may affect prey species and in turn marine mammals or sea turtles. For a more detailed description of these types of potential effect see Section 7.2.1.

Noise

ORE facilities can result in significant underwater marine noise and vibrations during construction (pile driving and drilling), with noise emitted during the operation phase as well (Nedwell and Howell 2004, Miller et al. 2009). The effects of this noise and vibration on wildlife will be a function of sound frequency, intensity, and duration in relationship to sensitivity of organisms in the vicinity of the noise source (Gill 2005; Scheidat et al. 2011).

Noise sources related to ORED include construction noise, especially pile-driving, operational noise, ship noise, and noise from decommissioning. There are other potential sources of very loud sounds that are not considered in the matrix, however may need to be considered as part of a particular project. These include seismic exploration, if necessary for geophysical site characterization, and explosives if needed for either construction or decommissioning.

The potential impacts of sound are significant for marine mammals. Their hearing is much more sensitive than sea turtles', and they are known to use sound in communication, navigation, foraging, and social behavior. Concern about Navy impacts has led to further refinements in the details of how Level A and Level B harassment are considered. Sound of sufficient intensity can physically damage the sensory cells in the inner ear to such a degree that they are unable to recover, causing permanent hearing damage or "permanent threshold shift" (PTS). Sounds of lower intensity can cause reductions in hearing sensitivity that the animal can recover from after sufficient time, known as a "temporary threshold shift" or TTS. PTS is considered to constitute Level A harassment, i.e., injury. TTS is considered to constitute Level B harassment. In addition, sounds that are not intense enough to cause TTS may nevertheless cause animals to alter their behavior, which also fits the definition of Level B harassment. Therefore Level B harassment has effectively been divided into two subtypes—TTS and behavioral disturbance. The threshold sound levels currently used by the National Marine Fisheries Service (NMFS) to regulate takes are:

- 190 dB re 1 μPa[4-1] for Level A for pinnipeds
- 180 dB re 1 μPa for Level A for cetaceans
- 160 dB re 1 μPa for Level B from impulsive sounds
- 120 dB re 1 μPa for Level B from continuous sounds

NRC (2000) recommended that the MMPA definition of "Level B harassment should be limited to meaningful disruption of biologically significant activities that could affect demographically important variables such as reproduction and longevity." Toward that end, the National Defense Authorization Act for FY2004 amended the MMPA to modify the definition of harassment relative to military readiness activities to include restrictions only when mammals were likely to be disturbed to the extent that natural behavior patterns would be "significantly abandoned or altered." That still leaves open the question of what constitutes "biologically significant activities" or "significant alterations of behavior patterns." NRC (2005) investigated the population-level consequences of acoustic disturbance and made a series of research recommendations. Thomsen et al. (2011) went further and analyzed trends in selected marine mammal populations in high-impact areas used extensively by the oil and gas industry and other users.

Given that the largest impacts on marine mammals from ORE facilities are predicted to be the sounds from construction (and decommissioning) and not from routine operations, there are probably substantially smaller differences in expected impacts from different spatial scales of development than there might be for other taxa (e.g., birds, fish). For an array of 100 wind turbines (Scale 2), or for several wind farms within a given region (Scale 3), it seems unlikely that pile-driving for all the individual structures would occur simultaneously. The sound intensity from pile-driving of a Scale 2 project will not be 100 times that of Scale 1 installation, but the duration of the noise will be substantially longer. The impacts of a Scale 2 or 3 project can be modeled based on monitoring data collected at one construction site. Impacts from single events could very well add up over the whole construction period.

Few studies exist on the potential effects of underwater sound on sea turtles, and most of those examined the effects of sounds of much longer duration than active sonar signals. Sea turtles might be affected by sounds of intensities sufficient to cause injury to cetaceans (> 180

[4-1] The decibel (dB) is a measurement unit that compares a quantity, on a logarithmic scale, to a standard reference level. Different reference levels are used for sound intensities measured in air or in water. The underwater standard reference sound level is 1 microPascal (μPa).

dB re 1 μPa). To quantify the potential impact on sea turtle stocks, a recent analysis was based on information for leatherback sea turtles in the Pacific Ocean (U.S. Navy, 2007). Leatherbacks were chosen for this analysis because they are the largest, most pelagic, and most widely distributed of any sea turtle, inhabit the oceanic zone, and are capable of transoceanic migrations. They are rarely found in coastal waters and are deep, nearly continuous divers with usual dive depths around 250 m. Based on a conservative estimate of 20,000 leatherback sea turtles for the Pacific basin, the possible number of times a leatherback could be within the 180-dB re 1 μPa sound field of a sonar vessel during transmissions was estimated to be less than 0.2 animals per year per vessel. Therefore, the potential for sonar operations to impact leatherback sea turtle stocks was concluded to be negligible, even when up to four systems are considered.

Marine mammals, especially the cetaceans (whales, dolphins, and porpoises) are known to use underwater sound for a variety of functions, including communication, social interactions, orientation and navigation, and foraging (Richardson et al. 1995; NRC 2005). All species are known or predicted to have very sensitive hearing, although the frequency range of maximum sensitivity varies among species. In recent years, a great deal of the regulatory effort in the U.S. federal government has been focused on dealing with the potential impacts of sound on marine mammals. The impact of noise on individuals or populations depends on both sound intensity and duration. All sources of noise related to ORED have the potential to affect marine mammals—and to a lesser degree, sea turtles (U.S. Navy 2007)—with the largest effects expected for the loudest and longest noise sources.

Understanding the range of impacts of sounds on marine mammals and sea turtles is very complicated. What is clear is that the loudest acoustic sources are those with the highest level of concern. There are six noise sources specified in the Impact Matrix. Ranked in order from highest to lowest intensity (i.e., highest to lowest concern), they are: pile driving, pile cutting during removal, directional drilling, vessel traffic during either installation or removal, and tonal sources during operation. Existing information is best about pile-driving noise, operational noise of wind turbines, and vessel noise. There seems to be fewer available data on noise from drilling, pile cutting, or operational noise from marine hydrokinetic (current or wave) installations.

EMF

Cetaceans and sea turtles have received attention with respect to induced magnetic fields around underwater transmission cables as it is hypothesized that they use the Earth's magnetic field to navigate during migration (Gill et al. 2005). However, there is very little data supporting the theory of magnetic orientation in cetaceans. If an effect does exist, transient mammals would likely only be temporarily affected by an induced magnetic field (Gill 2005). Moreover, since migration generally occurs in open water and away from the seabed, electromagnetic fields are unlikely to have a detrimental effect on whale migration (Gill et al. 2005).

Scale 1:

At Scale 1, none of the potential effects are expected to be serious (see Table 12). Acoustic effects and vessel collisions would have the highest levels of concern. The acoustic effects of pile cutting are predicted to be about the same or less than pile- driving. Ship collision risk should be relatively low, since the numbers of vessels and transits will be low. Mitigation should be straightforward—speed restrictions, protected species observers, and perhaps limits on transits at night or during reduced visibility.

Scale 2:

At Scale 2, the potential noise effects from pile driving or cutting is increased (see Table 13) due to the greater number of devices. Operational noise is also greater at this scale. The negative effects from construction or operational nosie could be more than simply additive from the number of units. However, given the sparse data for species other than porpoises and seals on the effects of ORED noise, there is still low certainty around these effects.

Risks of ship collision impacts will increase with the numbers of vessels and transits. Risks can still be mitigated; however scheduling issues may make it more difficult to limit transits to periods of clear visibility.

Lastly, reef effects at this scale may result in increased prey availability for marine mammal or sea turtles, however this effect is less understood.

Scale 3:

For multiple large-scale facilities in a region, the effects are predicted to be similar to Scale 2, however there is much less certainty (see Table 14). By virtue of the number of devices in the water, the likelihood of a chemical spill, accident, and leakages is increased. Acoustic impacts are similarly increased, especially with respect to pile-driving.

Table 12

Offshore Renewable Energy Effect Matrix- Scale 1, Marine Mammals and Sea Turtles

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strike by installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

Table 13

Offshore Renewable Energy Effect Matrix- Scale 2, Marine Mammals and Sea Turtles

Scale 2- Single Commercial Scale Facility			Technology Type													
			Wind				Currents				Waves					
			Foundation				Turbine Type				Device Type					
							Open Rotor		Shrouded							
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strikes with installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

Table 14

Offshore Renewable Energy Effect Matrix- Scale 3, Marine Mammals and Sea Turtles

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type												
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
			Monopile	Gravity	Tripod/lattice	Floating Mooring	Open Rotor		Shrouded		Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Potential Effect							Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring					
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strikes with installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

7.3. CONCLUSIONS

Overall, the Offshore Renewable Energy Effect Matrix revealed the following patterns:

- The potential effects from a project at Scale 1 (demonstration scale) were all characterized as negligible to minor mainly because of the small size of these projects and the shorter duration of construction and decommissioning activities.
- The potential effects associated with MHK technologies have a greater level of uncertainty across all Scales due the small number of deployed projects.
- The greatest amount of uncertainty for all technology types surrounds Scale 3 developments due to the lack of data at this scale.

Potential effects categorized as moderate or major effects will serve as a starting point in determining what effects need to be monitored at ORE facilities. This analysis is discussed in Section 8.

8. PROTOCOLS TO MONITOR EFFECTS

While the results of the Offshore Renewable Energy Effect Matrix (described in Section 7 and provided in Appendix C) are not meant to be static and should be updated frequently as new information is available, the current findings were used as a guidance tool to identify the potential effects that merit future monitoring. To begin, all potential effects categorized as moderate or major at any scale were identified (Table 15).

Table 15

Potential Effects Categorized as Moderate or Major in the Offshore Renewable Energy Effect Matrix

Benthic Habitat and Resources	Changes to currents, wave regime
	Disturbance from installation/removal device (including increased turbidity)
	Scour around structures
	Reef effects
	Leakage lubricants/fluids; Release maintenance chemicals
	Large spills or accidents
	Resuspension of pollutants in sediments
Fish	Rotating turbine blades
	Pressure gradients around rotor
	Large spills or accidents
	Operational noise (gears, mooring chains, etc.)
	Noise from pre-construction seismic surveying
	Noise from pile driving
	Noise from pile cutting during device removal
	EMF from power cable
	Habitat alteration/community composition
	Reef effects (aggregation)
Fisheries	Decreased Catchability during construction
	Decreased Catchability during operation
	Loss of access to grounds during construction
	Loss of access to grounds during operation - mobile gear fisheries
	Loss of access to grounds during operation - fixed and recreational fisheries
	Changes in species distribution
	Reef effects (aggregation)
	Damage/lost gear
Avian Species	Displacement or attraction to structure above surface of the water
	Displacement or attraction to structure below surface of the water
	Collision with rotating turbine blades
	Pressure gradients around rotor
	Leakage lubricants/fluids; Release maintenance chemicals
	Large spills or accidents

Marine Mammals and Sea Turtles	Reef Effects
	Strikes with installation or support vessels
	Operational noise (rotor, power train, cable strum)
	Noise from pile driving
	Noise from pile cutting during device removal

The potential release of toxic fluids, chemicals or other debris, as well as the risk of a large spill from a vessel accident was categorized under multiple topic areas as a moderate to major effect especially in rare cases, where large amounts of toxic substances are released into the environment. However, due to the relatively low likelihood of such an occurrence, it was determined that monitoring for this effect was not necessary. In addition, the implementation of plans such as oil spill response plans can minimize the damage caused by a release of toxic fluids, chemicals or other debris.

The remaining potential effects which merit the development of monitoring protocols are presented in Table 16. It is important to note that any particular project may or may not require monitoring for all of the following potential effects; however these will outline the issues for which standardized monitoring protocols will be established in year 2.

Table 16

Potential Effects for which Monitoring Protocols will be Developed

Benthic Habitat and Resources	
Scale 1 (Demonstration Scale)	Scour around device Changes in median grain size, or organic content Turbidity during construction/decommissioning Change in target species abundance and distribution (e.g, species of importance) Colonization density, composition of communities on foundations
Scale 2 (Commercial Scale)	Changes to seafloor morphology and structure (compared to pre-construction) Changes in median grain size, or organic content Turbidity during construction/decommissioning Change in target species abundance and distribution (e.g, species of importance) Change in density, diversity, dominance structure of infauna Colonization density, composition of communities on foundations Current speed/direction inside and outside farm
Scale 3 (Multiple Commercial Facilities in a Region)	Changes to seafloor morphology and structure (compared to pre-construction) Changes in median grain size, or organic content Change in target species abundance and distribution (e.g., species of importance) Change in density, diversity, dominance structure of infauna Hydrodynamics inside and outside farms throughout region
Fish	
Scale 1	Reef effects Blade strikes (tidal power)
Scale 2	Reef effects Changes to abundance/distribution Installation noise effects (for devices requiring pile driving) Operational noise effects EMF effects Blade strikes / pressure gradients (tidal power)
Scale 3	Reef effects Changes to abundance/distribution and community composition on regional scale Installation noise effects (for devices requiring pile driving) Operational noise effects EMF effects Blade strikes / pressure gradients (tidal power)
Fisheries	
Scale 1	Loss of access to grounds
Scale 2	Catchability during construction Catchability during operation Loss of access to grounds Changes in species distribution Reef effects (aggregation)
Scale 3	Catchability during construction Catchability during operation Loss of access to grounds Changes in species distribution Reef effects (aggregation)

Avian	
Scale 1	Vessel strikes causing chemical spill Displacement/ attraction Barrier effects – effects on foraging, roosting, migratory movements Collision mortality
Scale 2	Vessel strikes causing chemical spill Displacement/ attraction Barrier effects – effects on foraging, roosting, migratory movements Collision mortality
Scale 3	Vessel strikes causing chemical spill Displacement/ attraction Barrier effects – effects on foraging, roosting, migratory movements Collision mortality
Marine Mammals and Sea Turtles	
Scale 1	Vessel strikes Noise generated during all stages of development Disturbance or injury during all stages of development Changes in distribution or migratory routes
Scale 2	Vessel strikes Noise generated during all stages of development Disturbance or injury during all stages of development Changes in distribution or migratory routes
Scale 3	Vessel strikes Noise generated during all stages of development Disturbance or injury during all stages of development Changes in distribution or migratory routes Changes in life history and demographics

While all potential effects at Scale 1 (demonstration scale) were categorized as negligible to minor (Appendix C), it was determined that projects at this scale provide an opportunity to better understand potential effects through monitoring. Therefore, Table 6 includes effects at Scale 1 even though projects of this size are likely to pose the smallest effects to marine resources. The monitoring requirements of current permitted MHK demonstration projects in the U.S. (i.e. Snohomish County Public Utility District No. 1 2009; Verdant Power, LLC 2010; Reedsport OPT Wave Park, LLC, 2010) were examined when determining what to include in Scale 1.

In addition to developing protocols to monitor effects, protocols for conducting baseline assessments for each topic area (benthic habitat and resources, fish, fisheries, avian, marine mammals, and sea turtles) will also be developed in year 2. Baseline assessments are critical to properly identify and measure an environmental effect. The duration and extent of a baseline assessment will largely depend on the specific characteristics of a resource and the amount of seasonal or annual variability of the distribution of a species, population, resource or activity.

9. MONITORING DATA TO SUPPORT THE CUMULATIVE IMPACT ASSESSMENTS AND ASSOCIATED MODELS

Cumulative effects from ORE projects can be examined in different ways. One approach is to develop ecological indices and models that numerically evaluate the cumulative effects of a single project or from multiple projects. Key to the successful implementation of ecological indices and models is sufficient underlying data. Designing monitoring protocols and data collection methods to feed into these modeling tools is one way to ensure their effectiveness and applicability.

The appropriate spatial and temporal scale of data collection for a particular resource is key to accurately characterizing a resource and measuring the effect of an offshore renewable energy project on that resource. Spatial scales that are too small may mischaracterize the relative importance of an area. Temporal scales that are too short in duration may mischaracterize the level of variability of a resource within a particular area offshore. Conversely, spatial and temporal scales too large may become cost prohibitive, logistically unrealistic, or result in long lag times in data processing.

In order to explicitly address the spatial and temporal extent of the environmental data that is collected, a robust ecological classification scheme will be used in the creation of monitoring protocols. NOAA's Coastal and Marine Ecological Classification Standard (CMECS; Madden et al., 2010) will be used to unify each of the environmental data layers for streamlined input into ecological indices (such as the Ecological Valuation Index, Siting Evaluation Model and the Cumulative Impact Model designed in Year 2). CMECS uses a spatial and temporal framework to organize and classify ecoregional, geological, biological and hydrological marine datasets from ecosystems throughout North America. CMECS is currently being developed to be applicable and relevant to resource mapping and assessment efforts, and to use an ecosystem-based approach that is critical for describing reference states and ecosystem change in marine and coastal areas. CMECS and its applicability to the monitoring protocols developed will be discussed in much greater detail in Year 2.

10. CONCLUSIONS

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.3 report entitled *A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction,* serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This report focuses on understanding the potential effects associated with ORED and which effects need to be monitored.

The objectives of this report are as follows:

1. Identify any additional potential effects to the benthic habitat, fish and fisheries, marine mammals, sea turtles, birds, and bats OWE or MHK development on the OCS not discussed within the PEIS (MMS 2007).
2. Identify and categorize the level of effect and certainty of each potential effect of OWE and MHK at the following scales: demonstration scale (Scale 1), commercial scale (Scale 2), and multiple facilities within a region (Scale 3).
3. Outline potential effects that require monitoring at future OWE and MHK facilities and for which protocols will be developed in Year 2.
4. Discuss how data collected during monitoring protocols can be used to support cumulative impact assessments and associated models.

The results of the extensive literature review and the year-long process that engaged U.S. resource experts, European researchers and industry members of the Project Advisory Committee (Appendix A) found no new potential effects have been identified since the publication of the PEIS. While the level of understanding surrounding many of the potential effects of ORE has evolved over time, no new potential effects have been discovered since the publication date of the PEIS in 2007 (see Section 6).

Using the Offshore Renewable Energy Effect Matrix (described in Section 7 and provided in Appendix C) as a guidance tool, a list of potential effects that merit future monitoring were identified for each scale of development (see Table 16). These potential effects form the basis of what standardized monitoring protocols will be developed as part of this project in Year 2. While any particular project may or may not require monitoring for all of the potential effects identified in Table 16, these will outline the issues for which standardized monitoring protocols will be established in subsequent tasks of this project.

Monitoring protocols to address these potential effects will be designed to feed into the siting models and cumulative impact assessment tools developed in Year 2. Designing standardized monitoring protocols, siting models and cumulative impact assessment tools in conjunction with one another increases their overall compatibility and effectiveness. Throughout the creation of standardized monitoring protocols as part of this project, the appropriate spatial and temporal scale for each resource and effect will be considered and incorporated.

LIST OF REFERENCES

ABPmer Ltd, et al., 2010. A Further Review of Sediment Monitoring Data. Commissioned by COWRIE Ltd (project reference ScourSed-09), 115 pp.

Allen, B. M., and R. P. Angliss. 2010. *Alaska Marine Mammal Stock Assessments, 2009*. NOAA Technical Memorandum NMFS-AFSC-206. National Marine Fisheries Service, Seattle, WA.

Andersen, B., and J. Jakobsen. 1983. Noise Emission from Wind Turbine Generators. A Measurement Method, Danish Acoustical Institute Technical Report No. 109, Lyngby, Denmark: Danish Academy of Technical Sciences.

Antizar-Ladislao, B. 2008. Environmental levels, toxicity, and human exposure to tributyltin (TBT)-contaminated marine environment. A review. Environment International 34 (2008):292-308.

Baerwald, E. F., G. H. D'Amours, B. J. Klug, and R. M.R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology 18:695-696.

Baird, P. H. 1990. Concentrations of seabirds at oil-drilling rigs. Condor 92:768-771.

Balmori, A. 2005 Possible effects of electromagnetic field from phone masts on a population of white stork (Ciconia ciconia). Electromagnetic Biology and Medicine. 24: 109-119.

Balmori, A. 2009. Electromagnetic pollution from phone masts. Effects on wildlife. Pathophysiology doi:10.1016/j.pathophys.2009.01.007

Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381-287.

Barrios, L. and A. Rodríquez. 2004. Behavioral and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology 41:72-81.

BERR (United Kingdom Department of Business Enterprise and Regulatory Reform). 2008a. Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry - Technical Report. Available online at: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file43527.pdf.

BERR. 2008b. Review of the reef effects of offshore wind farm structures and their potential for enhancement and mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No: RFCA/005/0029P. Available online at: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file43528.pdf.

Boehlert, G. W. and A. B. Gill. 2010. Environmental and ecological effects of ocean renewable energy development: A current synthesis. Oceanography 23:68-81.

Boehlert, G.W., G.R. McMurray, and C.E. Tortorici, editors. 2008. Ecological Effects of Wave Energy Development in the Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-92.

Bouma, S., Lengkeek, W., 2009. Development of underwater flora- and fauna communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ). Report nr 08-220. Bureau Waardenburg bv, Nordzeewind, 46 pp.

Broström, G. 2008. On the influence of large wind farms on the upper ocean circulation. Journal of Marine Systems 74(2008):585–591.

Burger, J. and M. Gochfeld. 2002. Effects of Chemicals and Pollution on Seabirds. Pages 485-526 in E. A. Schreiber and J. Burger. Biology of Marine Birds. CRC Press, Boca Raton, Florida.

Cada, G., J. Ahlgrimm, M. Bahleda, T. Bigford, S.D. Stavrakas, D. Hall, R. Moursund, and M. Sale. 2007. Potential effects of hydrokinetic and wave energy conversion technologies on aquatic environments. Fisheries 32:174–181.

Cape Wind Associates, LLC. 2011. Cape Wind Energy Project, Nantucket Sound, MA Construction and Operations Plan. Prepared for Submission to: Bureau of Ocean Energy Management, Regulation and Enforcement. Prepared by: ESS Group, Inc.; Ocean Surveys, Inc.; SgurrEnergy, Inc. Project No. E159-504.1. February 4, 2011. 171 pp.

Carey, J.M., Keough, M.J., 2002. The variability of estimates of variance, and its effect on power analysis in monitoring design. Environmental Monitoring and Assessment 74: 225-41.

Carretta, J. V., K. A. Forney, M. S. Lowry, J. Barlow, J. Baker, D. Johnston, B. Hanson, R.L. Brownell Jr.m J. Robbins, D.K. Mattila, K. Ralls, M. M. Muto, D. Lynch, and L. Carswell. 2010. U.S. Pacific Marine Mammal Stock Assessments: 2009. NOAA Technical Memorandum NMFS-SWFSC-453. National Marine Fisheries Service, La Jolla, CA.

Carstensen, J., O. D. Henriksen, and J. Teilmann. 2006. Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). Marine Ecology Progress Series 321:295-308.

CEFAS (United Kingdom Centre for Environment, Fisheries and Aquaculture Science). 2005. Assessment of the Significance of Changes to the Inshore Wave Regime as a consequence of an Offshore Wind Array. Available online at: http://www.cefas.co.uk/media/410846/sid5_ae1227.pdf.

Chamberlain, D.E., M. R. Rehfisch, A.D. Fox, M. Desholm, and S. J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148:198-202.

Champ, M.A. 2003. Economic and environmental impacts on ports and harbors from the convention to ban harmful marine anti-fouling systems. Marine Pollution Bulletin 46: 935–940.

Clark, N.A. 2006. Tidal barrages and birds. Ibis 148:152-157.

Crawford R.L. and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. Journal of Field Ornithology 72:380–388.

Cooper. B. and Beiboer. F. 2002. Potential Effects of Offshore Wind Developments on coastal processes. Available online at: http://www.offshorewindenergy.org/reports/report_002.pdf.

DECC (United Kingdom Department of Energy and Climate Change) 2008a. Review of Round 1 sediment process monitoring data – lessons learnt. Available online at: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/policy/offshore/rag/complete/file50440.pdf.

DECC. 2008b. Dynamics of scour pits and scour protection – Synthesis report and recommendations (Milestones 2 and 3). Available online at: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/policy/offshore/rag/complete/file50448.pdf.

DeepCWind Consortium. 2011. Maine Deepwater Offshore Wind Report. Compiled by: University of Maine and James W. Sewall Company. Available online at: http://deepcwind.org/docs/OfficialOffshoreWindReport-22311.pdf. 567pp.

Dempster, T., and M. Taquet. 2004. Fish aggregation device (FAD) research: Gaps in current knowledge and future directions for ecological studies. Reviews in Fish Biology and Fisheries 14:21–42.

Desholm, M. 2009. Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90:2672-2679.

Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1:296–298.

Diederichs, A., T. Grünkhorn, and G. Nehls. 2008. Offshore wind farms—disturbance or attraction for harbour porpoises? First results of T-POD investigations in Horns Rev and Nysted. Pp. 42-49 in: P.G.H. Evans (ed.). Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts. ECS Special Publication Series No. 49, European Cetacean Society, Caeernarfon, Gwynedd, UK.

DOE (US Department of Energy). 2009. Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies. Prepared in response to the Energy Independence and Security Act of 2007, Section 633(B). US Department of Energy, Wind and Hydropower Technologies Program. 89 pp. + appendices.

DONG Energy and Vattenfall. 2006. Review Report 2005: The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farms Environmental impact assessment and monitoring. The Environmental Group. 150 pp.

DONG Energy, Vattenfall, The Danish Energy Authority, and The Danish Forest and Nature Agency. 2006. Danish Offshore Wind: Key Environmental Issues. November 2006. Available from: www.ens.dk

Dooling, R. 2002. Avian hearing and avoidance of wind turbines. Technical Report. NREL/TP-500-30844, Golden, Colorado.

Drewitt, A. L, and R. H.W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29-42.

Edrén, S. M. C., S. M. Andersen, J. Teilmann, J. Carstensen, P. B. Harders, R. Dietz, and L. A. Miller. 2010. The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. Marine Mammal Science 26:614-634.

Edŕen, S.M.E., J. Teilmann, R. Dietz, and J. Carstensen. 2004. Effects from the Construction of Nysted Offshore Wind Farm on Seals in Rødsand Seal Sanctuary Based on Remote Video Monitoring. Technical report to Energy E2 A/ S. National Environmental Research Institute, Roskilde.

Ehrich, S., Kloppmann, M.H.F., Sell, A.F., and Böttcher, U. 2006. Distribution and assemblages of fish species in the German waters of North and Baltic Seas and potential impact of wind parks. In: Offshore Wind Energy: Research on Environmental Impacts, Köller, J.; Köppel, J.; Peters, W., eds. New York: Springer Publishing.

EMEC. 2010. European Marine Energy Centre (EMEC) Ltd, 2010. http://www.emec.org.uk/

Engås, A., Lokkeborg, S., Ona, E., Soldal, A.V. 1996. Effects of seismic shooting on local abundance and catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus). Canadian Journal of Fisheries and Aquatic Science: 53, 2238-2249.

EQUIMAR. 2009. Deliverable D6.3.1 Uncertainties regarding environmental effects. A draft. Commission of the European Communities, Equitable Testing and Evaluation of Marine Energy Extraction Devices in terms of Performance, Cost and Environmental Impact, Grant agreement number: 213380. 19pp.

Everaert, J. and E.W.M. Stienen. 2008. Impact of wind turbines on birds in Zeebrugge (Belgium). Biodiversity and Conservation in Europe 7:103-117.

Exo, K.-M., O. Huppop, and S. Garthe. 2003. Birds and offshore wind farms: a hot topic in marine ecology. Wader Study Group Bulletin 100:50-53.

EWEA (European Wind Energy Association) 2009 "Wind Energy- The Facts." Accessed online at: www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF.pdf

Fernandez-Juricic, E. 2001. Avian spatial segregation at edges and interiors of urban parks in Madrid, Spain. Biodiversity and Conservation 10:1303–1316.

Fernie, K. J., D. M. Bird, R. D. Dawson, and P. C. Lague. 2000. Effects of electromagnetic fields on the reproductive success of American Kestrels. Physiological and Biochemical Zoology 73: 60-65.

Forman, R.T.T. and R. D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology 14: 36–46.

Fortune, F. and D. Ainsworth. 2011. Lessons Learned at the World's First Commercial Scale Tidal Turbine – SeaGen in Strangford Lough, Northern Ireland. U.S. Department of Energy, Marine and Hydrokinetic Environmental Research Webinar Series: Monitoring Technologies and Strategies for Marine and Hydrokinetic Devices Webinar. September 14, 2011. Available online at: http://mhk.pnnl.gov/wiki/index.php/DOE_MHK_Webinar_Series.

Fox, A.D., M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148:129-144.

Fristedt, T., P. Moren and P. Soderberg. 2001. Acoustic and Electromagnetic Noise Induced by Wind Mills: Implications for Underwater Surveillance Systems Pilot Study. Report No. FOI-R-233-SE. Swedish Defence Research Agency, Stockholm, Sweden.

Garthe, S. and O. Hüppop. 1999. Effect of ship speed on seabird counts in areas supporting commercial fisheries. Journal of Field Ornithology 70:28-32.

Gauthreaux, S.A. and C.G. Belser. 2006. Effects of artificial night lighting on migrating birds. Pages 67-93. In Ecologicial Consequences of Artificial Night Lighting. C. Rich and T. Longcore, Eds.: 67–93. Island Press. Washington, DC.

Gill, A. B. 2005. Offshore renewable energy: ecological implications of generating electricity in the coastal zone. Journal of Applied Ecology 42:605-615.

Gill, A.B., Kimber, J.A. 2005. The potential for cooperative management of elasmobranchs and offshore renewable energy development in UK waters. Journal of the Marine Biological Association of the United Kingdom, 85: 1075-1081.

Gehring, J, P. Kerlinger, and A. M. Manville. 2009.Communications towers, lights, and birds: successful methods of reducing the frequency of avian collisions. Ecological Applications 19:505-514.

Grassle, J.F., Elmgren, R., Grassle, J.P., 1981. Response of benthic communities in MERL experimental ecosystems to low level, chronic additions of No. 2 fuel oil. Marine Environmental Research, 4: 279-297.

Grecian, W. J., R. Inger, M. J. Attrill, S. Bearhop, B. J. Godley, M. J. Witt, and S. C. Votier. 2010. Potential impacts of wave-powered marine renewable energy installations on marine birds. Ibis 152:683-697.

Goss-Custard, J.D., R.M. Warwick, R. Kirby, S. McGrorty, R.T. Clarke, B. Pearson, W.E. Rispin, S.E.A. Le V. Dit Durell, and R.J. Rose. 1991. Towards predicting wading bird densities from predicted prey densities in a post-barrage Severn Estuary. Journal of Applied Ecology 28:1004–1026.

Hagerman, G. 2001. Southern New England Wave Energy Resource Potential. Paper presented at the Building Energy 2001, Tufts University, Boston, MA.

Hammond, J. 2008. ACCIONA Energía, A Leader in Renewable Energy. A Viable Marine Renewable Energy Industry: Pursuing Innovation and Reducing Lifecycle Costs. Presented at Roger William's Marine Law Symposium: A Viable Marine Renewable Energy Industry: Solutions to Legal, Economic and Policy Challenges. Bristol, RI. Available online at: http://law.rwu.edu/sites/marineaffairs/symposia/seventhMLS.aspx.

Hartung, R. 1995. Assessment of the potential for long-term toxicological effects of the Exxon Valdez oil spill on birds and mammals. Page 693-726 in P. G. Wells, J. N. Butler. Exxon Valdez oil spill: fate and effects in Alaskan waters. American Society for testing materials, Philadelphia, Pennsylvania.

Hatch, J.J. and S. Brault. 2007. Collision mortalities at Horseshoe Shoal of birds species of special concern. Report No. 5.3.2-1, Cape Wind Associates, Massachusetts.

Henfridsson, U., Neimane, V., Strand, K., Kapper, R., Bernhoff, H., Danielsson, O., Leijon, M., Sundberg, J., Thorburn, K., Ericsson, E. & Bergman, K. 2007. Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak. Renewable Energy 32: 2069–2084.

Hoffman, E., J. Astrup, F. Larsen, F. and S. Munch-Petersen. 2000. Effects of Marine Windfarms on the Distribution of Fish, Shellfish and Marine Mammals in the Horns Rev Area. Report to ELSAMPROJEKT A/S. Report No. Baggrundsrapport 24. Danish Institute for Fisheries Research, Lyngby, Denmark.

Horn, J. W., E. B. Arnett, and T. H. Kunz. 2008. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72:123-132.

Hötker, H., K.-M. Thomsen and H. Jeromin. 2006. Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation. Michael-Otto-Institut im NABU, Bergenhusen. http://bergenhusen.nabu.de/bericht/englische%20 windkraftstudie.pdf

Hubbard, H. H. and K. P. Shepherd. 1990. Wind turbine acoustics. NASA Technical Paper 3057 DOE/NASA 20320-77. Hampton, Virginia.

Inger, R., M. J. Attrill, S. Bearhop, A. C. Broderick, W. J. Grecian, D. J. Hodgson, C. Mills, E. Sheehan, S. C. Votier, M. J. Witt, and B. J. Godley. 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. Journal of Applied Ecology 46:1145-1153.

Jonkman, J., S. Butterfield, W. Musial, and G. Scott. 2009. Definition of a 5-MW reference wind turbine for offshore system development. National Renewable Energy Laboratory Tech. Report NREL/TP_500_38060. Golden, Colorado.

Kahlert, J., I.K., Petersen, A.D., Fox, M. Desholm, and I. Clausager. 2004. Investigations of birds during construction and operation of Nysted offshore wind farm at Rodsand. Annual status report 2003. NERI report. Kalo, Denmark: National Environmental Research Institute. 82pp.

Kaiser, M. J., M. Galanidi, D. A. Showler, A.J. Elliot, R.W.G. Caldow, E.I.S. Rees, R. A. Stillman, and W. J. Sutherland. 2006. Distribution and behavior of common scoter Melanitta nigra relative to prey resources and environmental parameters. Ibis 148:110-128.

Katranitsas, A., J. Castritsi-Catharios, and G. Persoone. 2001. The effects of a copper-based antifouling paint on mortality and enzymatic activity of a non-target organism. Marine Pollution Bulletin 46:1491-1494.

Kirshvink, J.L. 1997. Magnetoreception: Homing in on vertebrates. Nature 690:339–340.

Lambkin, D.O., Harris, J.M. and Coates, T., 2009. Coastal Process modeling for offshore wind farm environmental impact assessment: Best practice guide. COWRIE COAST-07-08. Available online at: http://www.offshorewind.co.uk/Assets/Coastal%20process%20modelling%20best%20practice%20guide%20Final%20report%20sept%2009.pdf.

Langhamer, O., D. Wilhelmsson, and J. Engström. 2009. Artificial reef effect and fouling impacts on offshore wave power foundations and buoys – a pilot study. Estuarine, Coastal and Shelf Science 82:426-432.

Langhamer, O., and D. Wilhelmsson. 2009. Colonization of fish and crabs of wave energy foundations and the effects of manufactured holes: A field experiment. Marine Environmental Research 68:151–157.

Langton, R., I. M. Davies, and B.E. Scott. 2011. Seabird conservation and tidal stream and wave power generation: Information needs for predicting and managing potential impacts. Marine Policy 35:623-630.

Larsen, J.K., and M. Guillemette. 2007. Effects of wind turbines on flight behaviour of wintering common eiders: Implications for habitat use and collision risk. Journal of Applied Ecology 44:516–522.

Leddy, K. L., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin 111:100-104.

Leighton, F. A. 1990. The toxicity of petroleum oils to birds: an overview. Pages 10-22 in Proceedings of the effects of oil on wildlife: research, rehabilitation, and general concerns.

Leijon, M., H. Bernhoff, M. Berg and O. Ågren. 2003. Economical considerations of renewable electric energy production – especially development of wave energy. Renewable Energy 28: 1201–1209.

Longcore, T., C. Rich, and S.A. Gauthreaux. 2008. Height, guy wires, and steady-burning lights increase hazard of communication towers to nocturnal migrants: a review and meta-analysis. Auk 125:485-492.

Luschi, P., S. Benhamou, C. Girard, S. Ciccione, D. Roos, J. Sudre. and S. Benvenuti. 2007. Marine turtles use geomagnetic cues during open-sea homing. Current Biology, 17:126–133.

Mackinson, S., Curtis, H., Brown, R., McTaggart, K., Taylor, N., Neville, S. & Rogers, S., 2006, A report on the perceptions of the fishing industry into the potential socio-economic impacts of offshore wind energy developments on their work patterns and income. Technical Series No. 133. Available online at: http://www.vliz.be/imisdocs/publications/123163.pdf

Maclean, I.M.D., H. Skov. and M. M. Rehfisch. 2007. Further use of aerial surveys to detect bird displacement by offshore windfarms. COWRIE Ltd, Cumbria, United Kingdom.

Maclean, I.M.D., L. J. Wright, D. A. Showler, and M. M. Rehfisch. 2009. A review of assessment methodologies for offshore wind farms. British Trust for Ornithology, COWRIE Ltd., United Kingdom.

Masden, E.A., D.T. Haydon, A.D. Fox, R.W. Furness, R. Bullman, and M. Desholm. 2009. Barriers to movement: Impacts of wind farms on migrating birds. ICES Journal of Marine Science 66:746–753.

Masden, E.A., D.T. Haydon, A.D. Fox, and R.W. Furness, R. Bullman, and M. Desholm. 2010. Barriers to movement: Modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. Marine Pollution Bulletin 60:1085-1091.

Meibner, K., Sordyl, H., 2006. Ecological research on offshore wind farms: International exchange of experiences; Chapter 1: Literature review of offshore wind farms with regard to benthic communities and habitats. German Federal Agency for Nature Conservation. pp 1-46.

Miller, J. H., G. R. Potty, K. Vigness Raposa, D. Casagrande, L. Miller, S. Crocker, R. Tyce, J. Preston, B. Roderick, J. Nystuen, and P. Scheifele. 2009. Environmental assessment of offshore wind power generation near Rhode Island: acoustic and electromagnetic effects on marine animals. Presentation, Acoustical Society of America meeting, San Antonio, Texas.

MMS (Minerals Management Service). 2007. Final Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use Facilities on the Outer Continental Shelf. October 2007. Available online at: http://ocsenergy.anl.gov/documents/fpeis/index.cfm.

MMS. 2009. Cape Wind Energy Project Final Environmental Impact Statement. January 2009. MMS EIS-EA, OCS Publication No. 2008-040. Available online at: www.mms.gov/offshore/RenewableEnergy/CapeWindFEIS.htm.

Montgomery, J., G. Carton, R. Voigt, C. Baker and C. Diebel. 2000. Sensory processing of water currents by fishes. Philosophical Transactions of the Royal Society of London B 355: 1325–1327.

Mueller-Blenkle, C., McGregor, P.K., Gill, A.B., Andersson, M.H., Metcalfe, J., Bendall, V., Sigray, P., Wood, D.T. & Thomsen, F., 2010, Effects of Pile-driving Noise on the Behaviour of Marine Fish. COWRIE Ref: Fish 06-08, Technical Report Available online at:http://www.offshorewindfarms.co.uk/Assets/COWRIE%20FISH%2006-08_Technical%20report_Cefas_31-03-10.pdf.

Musial, W. 2008a. Status of Wave and Tidal Power Technologies for the United States. Technical Report, NREL/TP-500-43240, Golden, Colorado. Available online at: http://www.nrel.gov/docs/fy08osti/43240.pdf.

Musial, W. 2008b. Offshore Wind Technology. Presentation at the American Wind Energy Association Offshore Wind Power Workshop, Wilmington, DE, September 8-10, 2008.

Musial, W., S. Butterfield, and B. Ram. 2006. Energy from Offshore Wind. Conference Paper NREL/CP500-39450. National Renewable Energy Laboratories, February 2006.

NMFS (National Marine Fisheries Service) 2003. Taking of marine mammals incidental to specified activities; Construction of the east span of the San Francisco-Oakland Bay Bridge; Notice of issuance of an incidental harassment authorization. Federal Register 68(220):54595-64609.

NRC (National Research Council). 1990. Decline of the Sea Turtles: Causes and Prevention. National Academy Press, Washington, DC.

NRC (National Research Council). 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academies Press, Washington, DC.

Nedwell, J., Langworthy, J., and Howell, D. 2003. Assessment of Sub-Sea Acoustic Noise and Vibration from Offshore Wind Turbines and its Impact on Marine Wildlife; Initial Measurements of Underwater Noise During Construction of Offshore Windfarms, and Comparison with Background Noise. COWRIE: Report No. 544 R 0424.

Nedwell, J., and D. Howell. 2004. A review of offshore windfarm related underwater noise sources. COWRIE Technical Report 544 R 0308, The Crown Estate, London, U.K.

Nicholls, B. and P. A. Racey. 2007. Bats avoid radar installations: could electromagnetic fields deter bats from colliding with wind turbines? Plos One 2:e297: 1-6.

Normandeau, Exponent, T. Tricas, and A. Gill. 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

Ogden, L.J.E. 1996. Collision course: the hazards of lighted structures and windows to migration birds. Report to WWF Canada and the Fatal Light Awareness Program. http://www.flap.org/new/ccourse.pdf

OSPAR (The Convention for the Protection of the Marine Environment of the North-East Atlantic) 2009. Assessment of the Environmental Impact of cables. Available online at: http://qsr2010.ospar.org/media/assessments/p00437_Cables.pdf.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torresh Jr. 1998. Fishing down marine food webs. Science 279: 860–863.

Pelc, R. and R. M. Fujita. 2002. Renewable energy from the ocean. Marine Policy 26:471-479.

Percival, S.M. 2001. Assessment of the effects of offshore wind in birds. DTA/Pub URN 01/1434. UK.

Percival, S.M. 2003. Birds and wind farms in Ireland: a review of potential issues and impact assessment. Unpubl. report. UK. 25 pp.

Petersen, I. K. 2005. Bird numbers and distributions in the Horns Rev offshore wind farm area. National Environmental Research Institute Report, Denmark.

Polagye, B., A. Copping, K. Kirkendall, G. Boehlert, S. Walker, M. Wainstein, and B. van Cleve. 2010. Environmental Effects of Tidal Energy Development: A Scientific Workshop. Unpublished Workshop briefing paper. University of Washington, Seattle. Available online: http://depts.washington.edu/nnmrec/workshop/docs/Tidal_energy_briefing_paper.pdf.

Polagye, B., Van Cleve, B., Copping, A., Kirkendall, K. (editors), 2011. Environmental effects of tidal energy development. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS F/SPO-116. 186 pp.

Poot, H., B. J. Ens, H de Vries, M. A. H. Donners, M. R. Wernand, and J. M Marquenie. 2008. Green light for nocturnally migrating birds. Ecology and Society 13:47

Popper, A.N., Carlson, T.J., Hawkins, A.D., and Southall, B.L. 2006. Interim criteria for injury of fish exposed to pile driving operations: a white paper. Available at: www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf. Last accessed April 10, 2010.

Popper, A.N., Hastings, M.C. 2009. The effects of anthropogenic sources of sound on fishes. Journal of Fish Biology, 75: 455-489.

Ranke, J. 2002. Persistence of antifouling agents in the marine biosphere, Environmental Science and Technology 36:1539–1545.

Reedsport OPT Wave Park, LLC. 2010. Reedsport OPT Wave Park Joint Explanatory Statement for the Settlement Agreement Regarding the Construction and Operation of the Reedsport OPT Wave Park, FERC No. 12713, Douglas County Oregon. Available online at: http://elibrary.ferc.gov/idmws/File_list.asp?document_id=13836497.

Rees, J., Larcombe, P., Vivian, C, and Judd, A. 2006. Scroby Sands Offshore Wind Farm – Coastal Processes Monitoring. Contract AE0262. Final Report for the Department of Trade and Industry. Available online at: www.cefas.co.uk/publications/miscellaneous-publications/ae0262.aspx.

RI CRMC (Rhode Island Coastal Resources Management Council). 2011. The Rhode Island Ocean Special Area Management Plan. Adopted October 19, 2010. Available online at: http://seagrant.gso.uri.edu/oceansamp/.

Richardson, W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA.

Rodmell, D.P., and Johnson, M.L. The Development of Marine Based Wind Energy Generation and Inshore Fisheries in UK Waters: Are They Compatible? In Johnson, M. and C. Wheatley, eds. Who Owns the Sea Workshop Proceedings, Tjarno, Sweden, 24 - 27 June 2002.

Ross, B.P., J. Lien, and R. W. Furness. 2001. Use of underwater playback to reduce the impact of eiders on mussel farms. ICES Journal of Marine Science, 58:517–524.

Scheidat, M., J. Tougaard, S. Brasseur, J. Carstensen, T. van Polanen Petel, J.Teilmann and P. Reijnders. 2011. "Harbour porpoises (*Phocoena phocoena*) and wind farms: a case study in the Dutch North Sea." Environmental Research Letters 6(2011): 025102 (10pp). doi:10.1088/1748-9326/6/2/025102

Smallwood, K. S., L. Rugge, and M. L. Morrison. 2009. Influence of behavior on bird mortality in wind energy developments. Journal of Wildlife Management 73:1082-1098.

Snohomish County Public Utility District No. 1. 2009. Admiralty Inlet Pilot Tidal Project: Draft License Application. Available online at: http://www.snopud.com/PowerSupply/tidal/aidla.ashx?p=1732

Spaulding, M. 2008. Sources of Renewable Ocean Energy in Rhode Island. Presentation to the Coastal Resources Management Council, March 11, 2008.

Tasker, M.L., P. Hope-Jones, B. F. Blake, T.J. Dixon, and A. W. Wallis. 1986. Seabirds associated with oil production platforms in the North Sea. Ringing and Migration 7:7-14.

Teilmann, J., J. Tougaard, and J. Carstensen. 2008. Effects from offshore wind farms on harbor porpoises in Denmark. Pp. 50-59 in: P.G.H. Evans (ed.). Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts. ECS Special Publication Series No. 49, European Cetacean Society,

Teilmann, J., J. Tougaard, and J. Carstensen. 2006a. Summary on harbour porpoise monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Teilmann, J., J. Tougaard, J. Carstensen, R. Dietz, and S. Tougaard. 2006b. Summary on seal monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Thomsen, F., K. Lüdemann, R. Kafemann and W. Piper. 2006. Effects of offshore wind farm noise on marine mammals and fish. Hamburg, Germany on behalf of COWRIE Ltd.

Tougaard, J., J. Carstensen, and J. Teilmann. 2009a. Pile driving zone of responsiveness extends beyond 20 km for harbour porpoises (Phocoena phocoena (L.)). Journal of the Acoustical Society of America 126:11-14.

Tougaard, J., J. Carstensen, J. Teilmann, and N. I. Bech. 2005. Effects of the Nysted offshore wind farm on harbor porpoises. NERI Technical Report, Ministry of the Environment, Denmark.

Turner, A., M. Barrett, and M. T. Brown. 2009. Processing of antifouling paint particles by Mytilus edulis. Environmental Pollution 157:215-220.

U.S. Navy. 2007. Final supplemental environmental impact statement for surveillance towed array sensor system low frequency active (SURTASS LFA) sonar. U.S. Navy, Arlington, Va.

Verdant Power, LLC. 2010. Pilot license application Roosevelt Island tidal energy project. FERC No. 12611. Available online at: http://www.theriteproject.com/Documents.html.

Votier, S. C., B. J. Hatchwell, A. Beckerman, R. H. McCleery, F. M. Hunter, J. Pellatt, M. Trinder, and T. R. Birkhead. Oil pollution and climate have wide-scale impacts on seabird demographics. Ecology Letters 8:1157-1164.

Wahlberg, M., and Westerberg, H. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Progress Series, 288: 295-309.

Walker, R., Weiss, L., Frojan, C.B., Basteri, D., Coggan, R., 2009. Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions, Benthic Ecology. Contract ME1117. CEFAS, Suffolk, UK. 19 pp.

Wang, D., M. Atlar, and R. Sampson. 2007. An experimental investigation on cavitation, noise, and slipstream characteristics of ocean stream turbines. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 221(2):219-231.

Waring, G. T., E. Josephson, K. Maze-Foley, and P. E. Rosel, eds. 2009. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2009. NOAA Technical Memorandum NMFS-NE-213. National Marine Fisheries Service, Woods Hole, MA.

Westerberg, H., and I. Lagenfelt. 2008. Sub-sea power cables and the migration behaviour of the European eel. Fisheries Management and Ecology 15:369–375.

Wiese, F. K., W. A. Montevecchi, G. K. Davoren, F. Huettmann, A. W. Diamond, and J. Link. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. Marine Pollution Bulletin 42:1285-1290.

Wilhelmsson, D., Malm, T., Thompson, R., Tchou, J., Sarantakos, G., McCormick, N., Luitjens, S., Gullström, M., Patterson Edwards, J.K., Amir, O. and Dubi, A. (eds.) (2010). Greening Blue Energy: Identifying and managing the biodiversity risks and opportunities of offshore renewable energy. Gland, Switzerland: IUCN. 102pp.

Wilhelmsson, D., T. Malm, and M. C. Öhman, M. C. 2006. The influence of offshore windpower on demersal fish. Journal of Marine Science 63:775-784.

Wilson, B. Batty, R. S., Daunt, F. & Carter, C. (2007) Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland, PA37 1QA. Available online at: http://depts.washington.edu/nnmrec/workshop/docs/Wilson_Collisions_report_final_12_03_07.pdf

Wiltschko, W. and R. Wiltschko. 2005. Magnetic orientation and magnetoreception in birds and other animals. Journal of Comparative Physiology A – Neuroethology and Sensory Neural and Behavioral Physiology 191:675–693

Zydlewski, G. 2011. Acoustic Monitoring of Fish and Their Interactions with the Ocean Renewable Power Company (ORPC) Device. U.S. Department of Energy, Marine and Hydrokinetic Environmental Research Webinar Series: Monitoring Technologies and Strategies for Marine and Hydrokinetic Devices Webinar. September 14, 2011. Available online at: http://mhk.pnnl.gov/wiki/index.php/DOE_MHK_Webinar_Series.

APPENDIX A- PROJECT ADVISORY COMMITTEE AND TOPIC AREA ADVISORS

Name	Affiliation
MANAGEMENT TEAM	
Jennifer McCann	University of Rhode Island (URI) Coastal Resources Center/ Rhode Island Sea Grant
Grover Fugate	Rhode Island Coastal Resources Management Council
Dr. John King	URI Graduate School of Oceanography
Dr. Peter Paton	URI Dept. of Natural Resources Science
Dr. Deborah French-McCay	ASA, Inc.
Dr. Malcolm Spaulding	URI Ocean Engineering
TOPIC LEADS/EXPERTS	
Benthos	
Dr. Emily Shumchenia	URI Graduate School of Oceanography
Siting and Cumulative Impact Indices	
Melanie Schroeder	ASA, Inc.
Eileen Graham	ASA, Inc.
Jill Rowe	ASA, Inc.
Danielle Reich	ASA, Inc.
Fisheries	
Dr. Sarah Smith	URI Coastal Resources Center/ Rhode Island Sea Grant
Dave Beutel	Rhode Island Coastal Resources Management Council
Dr. Andrew B. Gill	Cranfield University (United Kingdom)
Birds	
Dr. Peter Paton (lead)	URI Dept. of Natural Resources Science
Dr. Scott McWilliams	URI Dept. of Natural Resources Science
Kris Winiarski	URI Dept. of Natural Resources Science
Dr. Tony Fox	University of Aarhus, Denmark
Marine Mammals/Sea Turtles	
Dr. Robert Kenney (co-	URI Graduate School of Oceanography

lead)	
Dr. Malia Schwartz (co-lead)	URI Department of Fisheries, Animal and Veterinary Sciences

Cultural Resources

Dr. Rod Mather (lead)	URI Dept. of History
John Jenson	URI Dept. of History

Renewable Energy Technologies

Michelle Carnevale	URI Coastal Resources Center/ Rhode Island Sea Grant
Walt Musial	National Renewable Energy Laboratory/Natl. Wind Tech. Ctr.
Heidi Souder	National Renewable Energy Laboratory/Marine Hydrokinetics

TOPIC AREA ADVISORS

Birds

Dr. Eric Rexstad	University of St. Andrews, Scotland
Taber Allison	American Wind and Wildlife Institute
Jason Osenkowski	Rhode Island Department of Environmental Management

Marine Mammals/Sea Turtles

Debi Palka	National Marine Fisheries Service (NMFS)/Northeast Fisheries Science Center
Victoria R.C. Cornish	Marine Mammal Commission
Carrie Upite	NMFS
Thomas French	Massachusetts Division of Fisheries and Wildlife
Molly Lutcavage	University of Massachusetts - Amherst
Jack Musick	Virginia Institute of Marine Science
Dr. Frank Thomsen	Centre for Environment, Fisheries and Aquaculture Science (CEFAS, United Kingdom)

Cultural

Frank Cantelas	National Oceanic and Atmospheric Administration (NOAA)
Dr. James Allan	William Self Associates
Victor Mastone	Massachusetts Board of Underwater Archaeological Resources

Fish/Fisheries

Jeremy Collie	URI Graduate School of Oceanography
Susan Tuxbury	NMFS Northeast Regional Office
Chris Boelke	NMFS Northeast Regional Office
Chris Littlefield	The Nature Conservancy
Russ Brown	
Flaxen Conway	Oregon Sea Grant
Kaety Hildebrand	Oregon Sea Grant
Sarah Henkel	Oregon State University
Amy Van Atten	NOAA
Gary Graham	Texas Sea Grant
Keith Kirkendall	NOAA Northwest Region

Project Advisory Committee

Thomas E. Bigford	NOAA/NMFS/Office Hab. Cons.
Robert DeSista	U.S. Army Corps of Engineers
Ed LaBlanc	U.S. Coast Guard
Ru Morrison	Northeastern Regional Association of Coastal Ocean Observing Systems
Kris Ohleth	Ocean Conservancy
Sally McGee	The Nature Conservancy
John Primo	Bureau of Ocean Energy Management Regulation and Enforcement (BOEMRE)/Environmental Sciences Branch
David Bigger	BOEMRE/ Office of Offshore Energy
James Price	BOEMRE/ Environmental Sciences Branch
Kathleen Tyree	BOERME/Office of Offshore Energy
Michael Amaral	U.S. Fish and Wildlife Service
Doug Pfeister	Offshore Wind Development Coalition

Paul Rich	Deepwater Wind
Tom Noji	NOAA
Daniel Morris	NMFS Northeast Regional Office
Caleb E. Gordon	Normandeau Associates
Jon Boothryod	URI Geosciences
Brian Oakley	URI Geosciences
Todd Callaghan	Massachusetts Office of Coastal Zone Management Program
Matt Nixon	Maine State Planning Office
Brian Todd	Natural Resources Canada
Judy Soule	Nature Serve
Becky Allee	NOAA
Mark Finkbeiner	NOAA
Chris Madden	Nature Serve
Sam DeBow	URI GSO
Sue Tuxbury	NOAA
Barry Costa Pierce	RI Sea Grant
Kathy Goodwin	Nature Serve
Dennis Nixon	URI Graduate School of Oceanography
Alan Desbonnet	RI Sea Grant
Eric Rexstad	St Andrews University
Christopher Boelke	NOAA
Sami Grimes	NOAA
Justin Klure	Pacific Energy Ventures
Andrea Copping	Pacific Northwest National Lab
Gordon Waring	NOAA
Monique LaFrance	URI Graduate School of Oceanography
Annette Grilli	URI Ocean Engineering
Judy Soule	NatureServe

Dr. Chris Madden	NatureServe
Dr. Rebecca J. Allee	NOAA/Coastal Services Center
Kathy Goodin	NatureServe
Mark Finkbeiner	NOAA/Coastal Services Center

APPENDIX B- SUMMARY TABLES OF THE PEIS

Table 1 – Magnitude of Impacts from OWE Development on the OCS as stated in the PEIS (MMS, 2007).

*Note this table only summarizes the findings on seafloor habitat, fish resources & essential fish habitat (EFH), fisheries, marine mammals, marine and coastal birds, and sea turtles which are the topic areas focused on in this project. The PEIS examines additional effects to other resources.

Ecological Component	Project Phase/ Activity Type	Impact Level				
		Negligible	Minor	Moderate	Major	Notes
Seafloor Habitat	Pre-Construction					
	Noise and Disturbance from Surveys and Bottom Sampling	X				
	Meteorological Tower Installation/Decommissioning	X	X			Assumes avoidance of sensitive habitat when siting and not using explosives during removal.
	Construction					
	Disturbing Sediments	X	X			Assumes avoidance of sensitive habitat when siting
	Crushing of Benthic Organisms	X	X			Assumes avoidance of sensitive habitat when siting
	Increasing Turbidity	X	X			Assumes avoidance of sensitive habitat when siting
	Habitat Alteration	X	X			Assumes avoidance of sensitive habitat when siting
	Construction Noise on Benthic Species	Unknown	Unknown	Unknown	Unknown	
	Accidental Spills or Debris	X	X			Will depend on the size and toxicity of the spill

Ecological Component	Project Phase/ Activity Type	Impact Level				
		Negligible	Minor	Moderate	Major	Notes
	Operation					
	Habitat Alteration/ Scour	X	X			Assumes scour protection will be used when necessary
	Change to Community Composition (Reef Effects)					Will vary depending on site specific conditions
	Turbine Noise	Unknown	Unknown	Unknown	Unknown	Sensitivity of most species is unknown, more study needed
	Electromagnetic Fields	X	X			Sensitivity of most species is unknown, more study needed
	Accidental Spills or Debris		X	X		Will depend on the size and toxicity of the spill

	Decommissioning					
	Habitat Alteration or Disturbance	X	X			Use of explosives would increase impact
	Accidental Spills or Debris	X	X			
Fish Resources and EFH	Pre-Construction					
	Noise and Disturbance Surveys and Bottom Sampling	X				
	Installation/Decommissioning of a Meteorological Tower	X	X			Assumes avoidance of sensitive habitat when siting and not using explosives during removal.
	Construction					
	Sediment Disturbance and Settling	X	X			Depends on species mobility
	Crushing of Benthic Organisms	X	X			Depends on species mobility
	Increased Turbidity	X				Assumes increased turbidity will be short-term and localized
	Noise	X	X			Depends on species and persistence of noise
	Increased Vessel Traffic	X				
	Waste Discharge and Accidental Fuel Releases	X	X			
	Operation					
	Scouring Around Piles	X	X			Especially in environments with soft sediments, however scour protection will be used to minimize impacts

	Habitat Alteration and Change in Community Composition	X	X	X	X	Depends on prevalence of habitat type, species, and project magnitude; Assumes avoidance of sensitive habitat when siting
	Lighting	Unknown	Unknown	Unknown	Unknown	
	Service Vessel Traffic Noise	X				
	Turbine Noise and Vibration	X	X			Depends on intensity of noise and species; More study need on species sensitivity and/or ability to acclimate
	Electromagnetic Fields	Unknown	Unknown	Unknown	Unknown	More study needed on species sensitivity
	Accidental Spills or Debris (service vessels or wind facility)	X	X			Will depend on the size and toxicity of the spill
	Decommissioning					
	Noise	X	X			Use of explosives would increase impact
	Habitat Alteration	X	X			Returning site to original condition
	Accidental Spills/Debris Release	X	X			
Fisheries	Pre-Construction					
	Changes in Species Distribution/Abundance during Surveys or Meteorological Tower Installation	X				
	Space-use Conflicts/ Exclusion Around Survey Activity	X				Conflicts could be avoided by conducting surveys during periods of low fishing activity
	Navigational Hazard from Meteorological Tower	X				
	Construction					

	Changes in Species Distribution/Abundance	X				
	Noise	X				
	Space-use Conflicts/ Exclusion	X				
	Increased Vessel Traffic	X				
	Waste Discharge and Accidental Spills or Fuel Releases	X				
	Operation					
	Space-use Conflicts/Exclusion	X	X	X		Depends on location of project, fishing activity and gear type
	Service Vessel Traffic	X				
	Fish Abundance/ Catchability					May increase or decrease; Varies depending on fishery
	Navigation Hazards					Varies depending on location and size of project; Minimized through appropriate siting
	Waste Discharge and Accidental Fuel Releases	X				Will depend on the size and toxicity of the spill
	Gear Entanglement or Damage					Varies depending on location of project, fishing activity and gear type
	Decommissioning					
	Space-use Conflicts/ Temporary Exclusion	X				
	Reduced Catchabiltiy	X				
	Disturbance from Increased Vessel Activity	X				
	Waste Discharge and Accidental Spills or Fuel Releases	X				Will depend on the size and toxicity of the spill

Marine Mammals	Pre-Construction					
	Noise from Geological and Geophysical Surveys	X (most species)	X (T&E species)			Minimized through compliance with Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) requirements
	Installation/Decommissioning of a Meteorological Tower	X	X			Minimized through compliance with ESA and MMPA requirements
	Construction					
	Noise from Construction		X (most species)	X (some species)		Will vary depending on species hearing sensitivity
	Collision with Vessel Traffic		X (most species)	X	X	Impacts greatest for threatened and endangered species
	Noise from Vessel Traffic	X				Will vary depending on species hearing sensitivity
	Waste Discharge and Accidental Fuel Releases	X				Will depend on the size and toxicity of the spill
	Operation					
	Turbine Noise	X	X	X		Will vary depending on species hearing sensitivity; Greatest impact for those individuals with important feeding or mating areas nearby or nearby migratory routes
	Service Vessel Collision		X (most species)	X	X	Impacts greatest for threatened and endangered species

	Service Vessel Traffic Noise	X				Will vary depending on species hearing sensitivity
	Accidental Spills or Debris (service vessels and wind facility)	X				Will depend on the size and toxicity of the spill
	Entanglement with Buried Cables		X (gray whale)	X (gray whale)		
	Decommissioning					
	Noise	X	X			Assumes explosives not used
	Collision with Vessel Traffic	X	X			
	Waste Discharge and Accidental Fuel Release	X	X			Will depend on the size and toxicity of the spill
Marine and Coastal Birds	Pre-Construction					
	Collision with Meteorological Tower	X				
	Waste Discharge and Accidental Fuel Release	X				Will depend on the size and toxicity of the spill
	Construction					
	Cable Trenching	X	X	X		Depends on proximity to shore, amount of habitat loss
	Waste Discharge and Accidental Fuel Releases	X				Will depend on the size and toxicity of the spill
	Onshore Construction		X	X		Depends on duration of disturbance
	Offshore Construction	X	X	X		Depends on habitat type and species present

	Operation					
	Turbine Collisions		X	X	X	Depends on species and number affected
	Turbine Site Avoidance	Unknown	Unknown	Unknown	Unknown	
	Service Vessel Traffic	X				
	Accidental Spills or Debris (service vessels and wind facility)	X				Will depend on the size and toxicity of the spill
	Decommissioning					
	Site Avoidance	X				
	Disturbance from removal of structure	X				Assumes explosives not used
Sea Turtles	Pre-Construction					
	Noise of Geological and Geophysical Surveys	X (most species)	X (T&E species)	X	X	Moderate and Major impacts possible if occurs near breeding or aggregation areas
	Construction					
	Noise (Pile-driving and Vessels)		X			
	Cable Trenching		X	X		Depends on location
	Collision with Vessel Traffic		X (juveniles and adults)	X (hatchlings)		
	Waste Discharge and Accidental Fuel Release	X	X			Will depend on the size and toxicity of the spill
	Onshore Construction	X	X	X		Depends on proximity to nesting sites

	Operation					
	Turbine Noise	Unknown	Unknown	Unknown	Unknown	
	Electromagnetic Fields	Unknown	Unknown	Unknown	Unknown	
	Collision with Service Vessel Traffic	X	X	X (hatchlings)		
	Accidental Spills or Debris (service vessels and wind facility)	X	X			Will depend on the size and toxicity of the spill
	Operational Lighting			X	X	(if lighting disorients hatchlings)
	Decommissioning					
	Noise	X	X			
	Vessel Collision	X	X			
	Waste Discharge and Accidental Fuel Release	X	X			

Table 2– Magnitude of Impacts from MHK Development on the OCS as stated in the PEIS (MMS, 2007).

*Note this table only summarizes the findings on seafloor habitat, fish resources & essential fish habitat (EFH), fisheries, marine mammals, marine and coastal birds, and sea turtles which are the topic areas focused on in this project. The PEIS examines additional effects to other resources.

	Project Phase/ Activity Type	Impact Level				
		Negligible	Minor	Moderate	Major	Notes
Seafloor Habitat	Pre-Construction					
	Disturbing Sediments	X				
	Noise Associated with Surveys	X				
	Construction					
	Disturbing Sediments	X	X	X		Assumes avoidance of sensitive habitat when siting
	Crushing of Benthic Organisms	X	X			Assumes avoidance of sensitive habitat when siting
	Increased Turbidity	X	X			Assumes avoidance of sensitive habitat when siting
	Construction Noise on Benthic Species	Unknown	Unknown	Unknown	Unknown	
	Accidental Spills or Debris	X	X			Will depend on the size and toxicity of the spill
	Operation					
	Habitat Alteration/Loss	X	X	X		
	Noise	X	X			Sensitivity of most species is unknown, more study needed

	Project Phase/ Activity Type	Impact Level				
		Negligible	Minor	Moderate	Major	Notes
	Entrainment/Entrapment/Impingement	Unknown	Unknown	Unknown	Unknown	
	Changes to Community Composition	Unknown	Unknown	Unknown	Unknown	Will vary depending on site specific conditions
	Accidental Spills or Debris	X	X			Will depend on the size and toxicity of the spill
	Electromagnetic Fields	X	X			Sensitivity of most species is unknown, more study needed
	Decommissioning					
	Noise	X	X			Use of explosives would increase impact
	Habitat Alteration	X	X			
	Water Quality/Debris	X				

Fish Resources and EFH	Pre-Construction					
	Noise Associated with Surveys	X	X			
	Waste Discharge and Accidental Fuel Releases	X	X			
	Construction					
	Disturbance of Seafloor/ Crushing of Benthic Organisms	X	X			Depends on species mobility
	Turbidity/ Smothering	X				Assumes increased turbidity will be short-term and localized
	Noise	X	X			Depends on species and persistence of noise
	Waste Discharge and Accidental Fuel Releases	X	X			Will depend on the size and toxicity of the spill
	Operation					
	Habitat Alteration	X	X			Depends on prevalence of habitat type, species, and project magnitude
	Entrapment/Entrainment/Impingement	Unknown	Unknown	Unknown	Unknown	
	Changes in Community Composition and Species Abundance	X	X			
	Noise and Vibration	X	X			(dependant on intensity of noise and species)
	Electromagnetic Fields	Unknown	Unknown	Unknown	Unknown	
	Waste Discharge and Accidental Fuel Releases	X	X			Will depend on the size and toxicity of the spill
	Decommissioning					

	Noise	X	X			Use of explosives would increase impact
	Habitat Alteration	X	X			Returning site to original condition
	Water Quality/Debris/Accidental Spills	X	X			Will depend on the size and toxicity of the spill
Fisheries	Pre-Construction					
	Space-use Conflicts/ Exclusion Around Survey Activity	X				Conflicts could be avoided by conducting surveys during periods of low fishing activity
	Construction					
	Disturbance/Displacement from Fishing Grounds	X	X			
	Fish Abundance	X				
	Water Quality/Debris/Accidental Spill	X				
	Operation					
	Displacement	X	X	X		Depends on location of project, fishing activity and gear type
	Disturbance by Service Vessel Traffic	X				
	Fish Abundance/ Catchability					May increase or decrease; Varies depending on fishery
	Navigation Hazards	Unknown	Unknown	Unknown	Unknown	Varies depending on location and size of project; Minimized through appropriate siting
	Waste Discharge and Accidental Fuel Releases	X				Will depend on the size and toxicity of the spill
	Gear Entanglement or Damage	Unknown	Unknown	Unknown	Unknown	Varies depending on location of project, fishing activity and gear type

	Decommissioning					
	Disturbance/Displacement from Fishing Grounds	X	X			
	Water Quality/Debris/Accidental Spill	X				Will depend on the size and toxicity of the spill
Marine Mammals	Pre-Construction					
	Noise Associated with Surveys	X (most species)	X (T&E species)			Minimized through compliance with Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) requirements
	Construction					
	Noise		X (most species)	X (some species)		Will vary depending on species hearing sensitivity
	Vessel Strike		X (most species)	X	X	Impacts greatest for threatened and endangered species
	Waste Discharge and Accidental Fuel Releases	X				Will depend on the size and toxicity of the spill
	Operation					
	Noise		X	X		(More study necessary)
	Vessel Strike		X (most species)	X	X	Impacts greatest for threatened and endangered species
	Service Vessel Traffic Noise	X				Will vary depending on species hearing sensitivity

	Accidental Releases of Chemical or Fuels	X				Will depend on the size and toxicity of the spill
	Collision with submerged turbines /Entanglement with Buried Cables	X	X (gray whale)	X (gray whale)		
	Decommissioning					
	Noise	X	X			
	Vessel Strike	X	X			
	Water Quality/Debris/Accidental Spill	X	X			Will depend on the size and toxicity of the spill
Marine and Coastal Birds	Pre-Construction					
	Water Quality/Debris/Accidental Spills	X				Will depend on the size and toxicity of the spill
	Construction					
	Water Quality/Debris/Accidental Spills	X				Will depend on the size and toxicity of the spill
	Displacement from habitat	X	X	X		Depends on habitat type and species present
	Operation					
	Collisions	X	X			Depends on species and number affected; More study needed
	Displacement from Habitat	X	X			
	Disturbance from Vessel Traffic	X				
	Water Quality/Debris/Accidental Spills	X				Will depend on the size and toxicity of the spill

	Decommissioning					
	Water Quality/Debris/Accidental Spills	X	X			Will depend on the size and toxicity of the spill
	Disturbance from Vessel Traffic	X	X			
Sea Turtles	Pre-Construction					
	Noise from Surveys	X	X (T&E species)			More study needed
	Water Quality/Debris/Accidental Spill	X				
	Construction					
	Noise		X			More study needed
	Displacement from habitat	X	X	X		(dependent on location)
	Vessel Traffic Strikes		X (juveniles and adults)	X (hatchlings)		
	Water Quality/Debris/Accidental Spill	X				Will depend on the size and toxicity of the spill
	Operation					
	Noise	Unknown	Unknown	Unknown	Unknown	
	Electromagnetic Fields	Unknown	Unknown	Unknown	Unknown	
	Service Vessel Strikes		X	X		
	Entanglement (with Mooring Lines)	X				

	Entrainment (terminators)		X	X		(juveniles and hatchlings)
	Impediment to Movement	X	X			Especially and issue with attenuators
	Water Quality/Debris/Accidental Spill	X	X	X	X	Depends on size and toxicity of spill and proximity to habitat
	Decommissioning					
	Noise	X	X			
	Vessel Traffic Strikes	X	X			
	Water Quality/Debris/Accidental Spill	X	X			

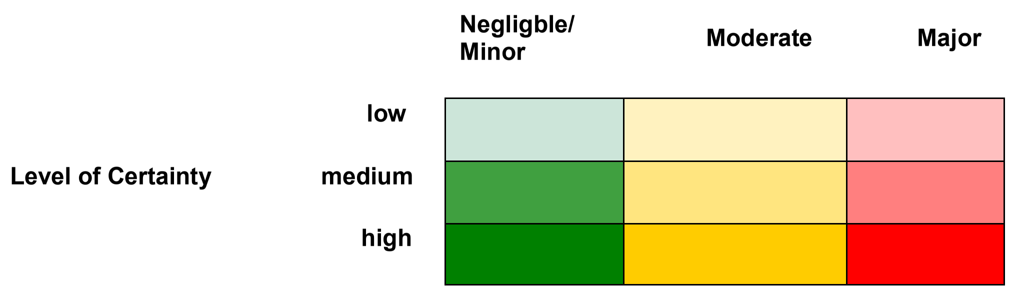
APPENDIX C- OFFSHORE RENEWABLE ENERGY EFFECT MATRIX

OFFSHORE RENEWABLE ENERGY EFFECT MATRIX

The purpose of this matrix is to
- Synthesize current understanding on potential effects by technology type
- Recognize the level of certainty surrounding potential impacts based on expert opinion and available scientific evidence
- Identify potential effects that merit monitoring or further scientific research

Blank cells represent no effect.

Legend **Level of Effect**



Level of Effect	**Definition**
Negligible	• No measurable effect.
Minor	• Should not influence or have only small effects on the affected resource, activity, or community.
Moderate	• Effects could moderately influence the resource, activity, or community, generally or for particular species.
Major	• Effects could significantly influence the resource, activity, or community, generally or for particular species.

Level of Certainty	**Definition**
Low	• Limited to no documentation or anecdotal evidence available
Medium	• Some documentation or anecdotal evidence available; no clear consensus among experts or within literature
High	•Well documented; consensus among experts and within the literature

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decommissioning													
	EMF	EMF from power cable													
Fish	Physical	Disturbance from installation device													
		Disturbance from removal of device													
		Disturbance from installation of power cable													
		Disturbance removal of power cable													
	Dynamic	Collision/Blade Strike													
		Pressure gradients around rotor													
		Velocity gradients around rotor													

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids during operation													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (gears, mooring chains, etc.)													
		Noise from pre-construction seismic surveying													
		Noise from vessels conducting project maintenance/monitoring													
		Noise from pile driving													
		Noise from vessel traffic during installation													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
		Noise from vessel traffic during removal													
	EMF	EMF from power cable													
	Community level impacts	Habitat alteration/community composition													
		Reef effects (aggregation)													
Fisheries		Decreased Catchability during construction													
		Decreased Catchability during operation													
		Loss of access to grounds during construction													
		Loss of access to grounds during operation - mobile fishing gear													
		Loss of access to grounds during operation - fixed and recreational fishing gear													

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		Changes in species distribution													
		Reef effects (aggregation)													
		Damage/lost gear													
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation, maintanence and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													

Scale 1- Individual Device/ Demonstration Project			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/ lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strike by installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

Scale 2- Single Commercial Scale Facility			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decommissioning													
	EMF	EMF from power cable													
Fish	Physical	Disturbance from installation device													
		Disturbance from removal of device													

Scale 2- Single Commercial Scale Facility			Technology Type													
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
Potential Effect			Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		Disturbance from installation of power cable													
		Disturbance removal of power cable													
	Dynamic	Collision/Blade Strike													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids during operations													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (gears, mooring chains, etc.)													
		Noise from pre-construction seismic surveying													
		Noise from pile driving													
		Noise from vessel traffic during installation													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
		Noise from vessel traffic during removal													
	EMF	EMF from power cable													
	Community level	Habitat alteration/community composition													

Scale 2- Single Commercial Scale Facility			Technology Type													
			Wind				Currents				Waves				
			Foundation				Turbine Type				Device Type				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
	impacts	Reef effects (aggregation)													
Fisheries		Decreased Catchability during construction													
		Decreased Catchability during operation													
		Loss of access to grounds during construction													
		Loss of access to grounds during operation - mobile gear fisheries													
		Loss of access to grounds during operation - fixed and recreational fisheries													
		Changes in species distribution													
		Reef effects (aggregation)													
		Damage/lost gear													
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradient around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release													

Scale 2- Single Commercial Scale Facility			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation, maintenance and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strikes with installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													

Scale 2- Single Commercial Scale Facility			Technology Type												
			Wind				Currents				Waves				
			Foundation				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type												
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
Benthic Habitat and Resources	Physical	Changes to currents, wave regime													
		Disturbance from installation/removal device (including increased turbidity)													
		Disturbance from installation of power cable (including trenching)													
		Disturbance removal of power cable													
		Scour around structures													
		Smothering by excavated sediments													
		Reef effects													
		Increase in sediment temperature around cable													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Noise and vibration before and during construction; during operation; during decommissioning													
	EMF	EMF from power cable													
Fish	Physical	Disturbance from installation device													
		Disturbance from removal of device													
		Disturbance from installation of power cable													
		Disturbance removal of power cable													

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type													
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Open Rotor		Shrouded		Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
							Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring					
	Dynamic	Collision/Blade Strike													
		Pressure gradients around rotor													
		Velocity gradients around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids during operations													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (gears, mooring chains, etc.)													
		Noise from pre-construction seismic surveying													
		Noise from pile driving													
		Noise from vessel traffic during installation													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
		Noise from vessel traffic during removal													
	EMF	EMF from power cable													
	Community level impacts	Habitat alteration/community composition													
		Reef effects (aggregation)													
Fisheries		Decreased Catchability during construction													
		Decreased Catchability during operation													
		Loss of access to grounds during construction													
		Loss of access to grounds during operation - mobile gear fisheries													

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type												
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		Loss of access to grounds during operation - fixed and recreational fisheries													
		Changes in species distribution													
		Reef effects (aggregation)													
		Damage/lost gear													
Avian Species	Physical	Displacement or attraction to structure above surface of the water													
		Displacement or attraction to structure below surface of the water													
		Disorientation or attraction from lighting													
		Disturbance from installation device or transmission cable													
		Disturbance from removal of device or transmission cable													
	Dynamic	Collision with rotating turbine blades													
		Pressure gradients around rotor													
		Velocity gradient around rotor													
		Rotor wake													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation,													

Scale 3- Multiple Commercial Scale Facilities in a Region			Technology Type												
			Wind				Currents				Waves				
			Foundation System				*Turbine Type*				*Device Type*				
							Open Rotor		Shrouded						
		Potential Effect	Monopile	Gravity	Tripod/lattice	Floating Mooring	Bottom Mounted	Floating Mooring	Bottom Mounted	Floating Mooring	Point Absorber	Wave Attenuator	Oscillating Water Column	Oscillating Wave Surge Converter	Overtopping
		maintenance and removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													
	Energy	Changes to foraging due to changes in turbulent dissipation/boundary layers													
		Changes to foraging due to changes to wave energy regime													
Marine Mammals and Sea Turtles	Physical	Reef Effects													
		Entanglement with mooring lines or cables													
	Dynamic	Collision with or avoidance of rotating turbine blades													
		Strikes with installation or support vessels													
	Chemical	Diffusion/flaking marine coating													
		Leakage lubricants/fluids; Release maintenance chemicals													
		Large spills or accidents													
		Chemicals discharged during installation or removal													
		Resuspension of pollutants in sediments													
	Acoustic	Operational noise (rotor, power train, cable strum)													
		Noise from pile driving													
		Noise from vessel traffic during installation or removal													
		Noise from directional drilling for power cable													
		Noise from pile cutting during device removal													
	EMF	EMF from power cable													

TASK 1.3

EXISTING U.S AND INTERNATIONAL MONITORING PROTOCOLS FOR OFFSHORE RENEWABLE ENERGY DEVELOPMENT AND OTHER MARINE CONSTRUCTION

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.2 report, entitled Report on Monitoring the Potential Effects of Offshore Renewable Energy, serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This literature review is a summary and comparative evaluation of existing monitoring protocols and practices used to monitor environmental effects of offshore renewable energy development to benthic habitat and resources, fisheries, marine mammals, sea turtles, and avian species. The protocols summarized include those used in offshore renewable energy projects and other types of marine construction activities, both within the United States and around the world.

The objectives of this report as stated in the contract no. M10PC00097 are to:

Conduct a comprehensive literature review of all protocols and relevant monitoring requirements in the United States relevant to offshore marine construction and development

Conduct a comprehensive review of the monitoring standards and methodologies used to evaluate the impacts of wind and hydrokinetic projects in Europe.

Complete a literature review and critique of other recommended monitoring practices from the scientific literature for each of the topic areas.

TASK 1.3

A COMPREHENSIVE REVIEW AND CRITIQUE: EXISTING U.S AND INTERNATIONAL MONITORING PROTOCOLS FOR OFFSHORE RENEWABLE ENERGY DEVELOPMENT AND OTHER MARINE CONSTRUCTION

Contributing Authors:

Robert Kenney, URI Graduate School of Oceanography
Peter Paton, URI College of Environmental and Life Sciences
Malia Schwartz, URI Graduate School of Oceanography
Emily Shumchenia, URI Graduate School of Oceanography
Sarah Smith, URI Coastal Resources Center
Kristopher Winiarski, URI College of Environmental and Life Sciences

EXECUTIVE SUMMARY

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.2 report, entitled Report on Monitoring the Potential Effects of Offshore Renewable Energy, serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This literature review is a summary and comparative evaluation of existing monitoring protocols and practices used to monitor environmental effects of offshore renewable energy development to benthic habitat and resources, fisheries, marine mammals, sea turtles, and avian species. The protocols summarized include those used in offshore renewable energy projects and other types of marine construction activities, both within the United States and around the world.

The objectives of this report as stated in the contract no. M10PS00152 are to:

1. Conduct a comprehensive literature review of all protocols and relevant monitoring requirements in the United States relevant to offshore marine construction and development
2. Conduct a comprehensive review of the monitoring standards and methodologies used to evaluate the impacts of wind and hydrokinetic projects in Europe.
3. Complete a literature review and critique of other recommended monitoring practices from the scientific literature for each of the topic areas.

Various monitoring methodologies and protocols are discussed here, including their applicability for monitoring the environmental effects of offshore renewable energy development. Those protocols that are either required by federal agencies in the United States for

marine construction or other projects, or protocols that are considered best management practices, are highlighted. Those monitoring protocols being required in Europe for current offshore renewable energy projects are also discussed. The summary also includes methodologies used in academic and applied research projects within these topic areas. Finally, Section 6.0 summarizes existing permits and applications for offshore renewable energy projects in the United States, including current and future monitoring plans for these projects.

This report provides the URI team with the framework to develop standardized monitoring protocols for offshore renewable energy projects in the United States that allow for the collection and analysis of scientifically valid and comparable data. The development of standardized protocols is critical to detecting and measuring environmental impacts as they can provide data that can be compared across sites, and even across regions. It must be recognized that the appropriate monitoring protocols for a given project will necessarily be project- and site-specific, determined by the size of the project and the potential for environmental effects, determined by the location and the species present at the project site. Nevertheless, standardized monitoring protocols will allow for comparison and aggregation of data between sites, and will result in a better understanding of the environmental effects of offshore renewable energy projects. These standardized protocols will also feed into the development in Year 2 of the project of a set of tools to measure the cumulative effects of offshore renewable energy on the marine environment. The development of such tools requires standardized data that can be input into the tools and easily compared. As recommendations are made for standardized protocols based on the findings of this literature review, considerations of the most suitable protocols include the cost, ease of use, reliability, and ability to compare data from various methods. This report has been reviewed extensively by the Project Advisory Committee and the topic area advisors, assembled for the purposes of providing expert input and review to the process of developing this document and ultimately the protocols.

For any type of monitoring, it is critical to conduct baseline assessments that provide sufficient information to be compared with construction and post-construction monitoring data. These assessments should employ the same methods as later monitoring in order to compare data and detect changes in the resource being studied. It is also important that data are collected post-construction over a sufficient time period to detect effects that may not be immediately apparent. In collecting data for the purposes of monitoring, it is essential to consider both spatial and temporal variation. Many studies conducted to date measuring environmental effects from offshore renewable energy projects employ a Before-After-Control-Impact (BACI) design, which allows for a control area against which to compare spatial and temporal effects. Some authors within the literature have recommended a Beyond BACI design, which allows for multiple control sites to account for natural spatial variation. There is no agreement in how many control sites should be used, nor does there appear to be consistency in the amount of data collected, for how long and in what time periods.

Overall, the literature review has found that, while many types of monitoring protocols exist and are currently employed, there are few standards for monitoring within any of these subject areas. While there is considerably more documentation of offshore wind energy projects than marine hydrokinetic projects, because there have been many more offshore wind energy projects developed within the last decade, monitoring data for any offshore renewable energy project are sparse. Within Europe, despite the proliferation of offshore wind facilities, most monitoring for effects does not follow any recognized standard, and there is little consistency in the data collected at each site. There have been attempts to make some recommendations for monitoring protocols, and Germany has adopted standards for monitoring Offshore Renewable Energy Developments (ORED). Existing monitoring practices are also inconsistent between countries. Within the United States, most other offshore development industries, including the offshore oil and gas industry, do not have standardized protocols for monitoring the effects of these activities. There are currently no specified protocols for protected marine species monitoring and mitigation for potentially harmful activities in U.S. waters. Many other potential effects of offshore activities, such as the effects of noise, or the disturbance caused by the installation of a device, appear to be monitored inconsistently if at all.

A COMPREHENSIVE REVIEW AND CRITIQUE: EXISTING U.S AND INTERNATIONAL MONITORING PROTOCOLS FOR OFFSHORE RENEWABLE ENERGY DEVELOPMENT AND OTHER MARINE CONSTRUCTION

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This report serves as the first deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This deliverable, along with the Task 1.2 report, entitled Report on Monitoring the Potential Effects of Offshore Renewable Energy, serve as the foundation for the creation of protocols and modeling tools which will be developed in Year 2 of the contract. This literature review is a summary and comparative evaluation of existing monitoring protocols and practices used to monitor environmental effects of offshore renewable energy development to benthic habitat and resources, fisheries, marine mammals, sea turtles, and avian species. The protocols summarized include those used in offshore renewable energy projects and other types of marine construction activities, both within the United States and around the world. The objectives of this report as stated in the contract no. M10PS00152 are to:

1. Conduct a comprehensive literature review of all protocols and relevant monitoring requirements in the United States relevant to offshore marine construction and development
2. Conduct a comprehensive review of the monitoring standards and methodologies used to evaluate the impacts of wind and hydrokinetic projects in Europe.
3. Complete a literature review and critique of other recommended monitoring practices from the scientific literature for each of the topic areas.

Offshore Renewable Energy Developments (ORED) provide the potential to generate large amounts of clean, low carbon energy in the United States. However, they are not without potential environmental effects. Monitoring of these devices is essential to determine what these effects might be, and how extensive they are likely to be. Monitoring should be effective, providing sufficient data to make definitive statements about the results of the study, even when conclusively determining primary or secondary effects is not possible. The offshore renewable energy devices that will require monitoring include wind turbines and marine hydrokinetic technology (MHK) devices, which include those harnessing wave and tidal energy. Several offshore wind energy facilities exist in Europe, of which some have been in place for several years, and thus some of the effects of these particular devices have been studied and are somewhat understood. Wave and tidal energy devices are newer and presently exist only at the demonstration scale; the potential effects of these are less well documented. Many of the potential effects of these devices will be similar, by virtue of being devices placed in the water, requiring construction or installation of some sort, and requiring cables connecting them to each other and to land. The devices also differ in some important respects. For more information on the various types of devices and their potential effects, please see Deliverable 1.2 for this contract, Report on Monitoring the Potential Effects of Offshore Renewable Energy.

This document was developed by reviewing literature, including both scientific literature and regulatory documents, relevant to ORED monitoring. This review included literature related to other types of offshore development. While the literature review is not comprehensive of all possible examples of monitoring, an attempt was made to include a broad range of monitoring protocols. Those protocols that are either required by federal agencies in the United States for marine construction or other projects, or protocols that are considered best management practices, are highlighted. Those monitoring protocols being required in Europe for current offshore renewable energy projects are also discussed. The summary also includes methodologies used in academic and applied research projects within these topic areas. Finally, Section 6 summarizes existing permits and applications for offshore renewable energy projects in the United States, and what the monitoring plans are for these projects.

The goal of this document is to present an overview and discussion of various protocols and standards that could be applied to monitoring effects of offshore renewable energy projects in order to support the development of a set of standardized protocols. It must be recognized that the appropriate monitoring protocols for a given project will necessarily be project- and site-specific, determined by the size of the project and the potential for environmental effects, determined by the location and the species present at the project site. Nevertheless, standardized monitoring protocols will allow for comparison and aggregation of data between sites, and will result in a better understanding of the environmental effects of offshore renewable energy projects. These standardized protocols will also feed into the development in Year 2 of the project of a set of tools to measure the cumulative effects of offshore renewable energy on the marine environment. The development of such tools requires standardized data that can be input into the tools and easily compared.

2. BENTHIC HABITAT AND RESOURCES

2.1. TYPES OF MONITORING AND THE POTENTIAL EFFECTS THEY ADDRESS

This section of the review is focused on monitoring the changes that are expected to occur to the benthic environment as a result of offshore renewable energy construction, operation and decommissioning. When the project team considered the range of offshore renewable energy technology types and the existing research on potential impacts (see Task 1.2, Report on Monitoring the Potential Effects of Offshore Renewable Energy), it was determined that the greatest changes that are also most likely to occur to the benthic environment are due to physical disturbance to the seabed resulting from the construction and presence of structures on the seafloor. In most cases, the device type (i.e., wind, tidal, wave) does not influence the level of impact. The degree and nature of the impact is primarily controlled by the numbers and types of foundations placed on the seafloor. Exceptions include tidal and wave energy devices, where energy-removal from the water column above the benthic environment may cause additional impacts, although with a high degree of uncertainty (see Renewable Energy Effect Matrix in Task 1.2; Polagye et al. 2010). Each marine hydrokinetic technology type that was examined utilized a type of mooring, foundation, or structure in contact with the seabed, and all were associated with subsea cables laid on the seafloor or within the seabed. Whereas the type of impact from each of these structures is, for the most part, the same (physical disturbance), the degree of impact will be different depending on the nature of the structure and construction method. This difference in foundation design is an important consideration because the type of foundation design has contributed more to observed differences in benthic community structure between offshore energy development sites than the difference in salinity between sites at Horns Rev and Nysted farms in Denmark (Leonhard and Birklund 2006).

Construction, operation and decommissioning of structures on the seafloor will affect both abiotic (non-living) and biotic (living) elements. In addition, impacts are expected at very local (i.e., species-level) and very broad (i.e., geomorphological) scales. The project team reviewed monitoring strategies that consider these four issues. Examples of potential abiotic effects include changes to seabed morphology, scour, and increased suspended sediments. These changes can translate to either losses or gains in benthic diversity and abundance, or shifts in benthic community composition. In the following sections, the tools and methods commonly used to monitor these impacts on the benthic environment are discussed.

2.1.1. Baseline Assessments

The purpose of a baseline study is to not only create an inventory of benthic resources that are present prior to development, but perhaps more importantly, to assess the natural variability of the environment prior to development. By measuring natural variability, one can then compare this baseline variability to post-impact variability and hopefully determine how human activities are affecting the benthic environment. The framework for what constitutes an "effect" is discussed in section 2.1.2.2 ("Statistical design"). Overall, it is acknowledged that natural variation is high in benthic communities, and therefore at least two separate sampling efforts should be undertaken for a pilot or baseline study (Carey and Keough 2002; Walker et al. 2009).

For studies of the benthic environment, the same methods are often used for both baseline assessments and the subsequent monitoring, and in most cases, continuity in methodology and instrumentation is essential in order to detect change (OSPAR 2002). The commonly utilized tools for baseline assessments and monitoring for the effects of local- and broad-scale physical disturbance on the benthic environment are discussed below.

Geophysical surveys: Abiotic and biotic; local and broad scale. Swath bathymetry and side scan sonar data collected with 100% coverage in the area of development can characterize seabed morphology, habitat structure, natural variability of bed levels, and substrate composition (Brown and Collier 2008). Repeated surveys can then be used to monitor bedform movement, variability of bed levels adjacent to foundations and changes to substrate composition (ABPmer Ltd. et al. 2010). Subbottom acoustics can be used to characterize sediment structure with depth in order to estimate the scour potential of the seabed (ABPmer Ltd. et al. 2010). Side scan sonar backscatter has been used to detect the presence of seagrasses (Lefebvre et al. 2009) and shellfish reefs (Taylor 2001), which are important biological elements to avoid or monitoring closely during development. Acoustic Doppler Current Profilers (ADCPs) may be used to record current speeds and wave heights and periods in order to assess impacts on hydrodynamics (Van Den Eynde et al. 2010).

Underwater video/photography: Abiotic and biotic; local and broad scale. Sled-operated underwater imagery can be used to supplement and/or support the interpretation of acoustic maps (Meibner and Sordyl 2006) by providing information on substrate type, bed configuration, and biotic cover (OSPAR 2002). Large, mobile epifauna, that are difficult to sample with other methods, are more easily assessed and monitored using underwater video (ESS Group, Inc. 2011). Quantification of benthic fauna may take the form of presence/absence (e.g., ESS Group, Inc. 2011), percent cover or frequency of occurrence (e.g., Leonhard et al. 2006). Underwater imagery is likely the most cost-effective method for assessing and monitoring hard-bottom fauna and flora, since the alternative involves diver-based surveys, which are more resource-intensive

(Sheehan et al. 2010). Diver- or ROV-operated video/photography are more commonly used to monitor the colonization and/or biofouling of structures once they are in place on the seabed (Meibner and Sordyl 2006; Leonhard et al. 2006; Bouma and Lengkeek 2009; Walker et al. 2009). Additionally, video may be used to examine other anthropogenic influences on the seabed (e.g., caused by fisheries) (BSH 2007).

Grab samples: Abiotic and biotic; local scale. Grab samples are the primary tool used to sample soft-bottom substrates. Particle size and organic content analyses of sediments from grabs can be used to ground-truth acoustic features (Orpin and Kostylev 2006; Anderson et al. 2008; Brown and Collier 2008), model surficial sediment distribution (Verfaillie et al. 2009), and plan an appropriate stratified sampling design for benthic communities (Jarvis et al. 2004; Meibner and Sordyl 2006; Walker et al. 2009). Depending on the target area, sediment chemistry analyses (e.g., metals concentration) may be appropriate as well (Walker et al. 2009). For example, in areas where sediment contamination is a concern, baseline concentrations should be defined before seabed disturbance causes sediment re-suspension and potential transportation or redistribution of contaminants (ABPmer Ltd. et al. 2010). Grab samples are also the primary quantitative method for characterizing benthic infaunal and epifaunal communities. The accepted best practice for baseline and monitoring projects is for macrofauna to be identified to the lowest possible taxonomic level and quantified (OSPAR 2002). It is especially important with grab samples to include replicates (i.e., 3 samples per station location), measure the sample volume and establish criteria for sample rejection (i.e., less than 50% full) (OSPAR 2002). Benthic communities can be characterized and monitored in a number of ways, depending on the geographic area, the anticipated impacts of development, and the project resources available. If there are species of special commercial or cultural importance, then these may dominate the benthic community analysis and be examined separately from other species (e.g., Proctor et al. 2003). Univariate metrics of benthic community structure and function include abundance, diversity, richness, evenness, and biomass. In the EU, AMBI (AZTI Marine Biological Index) score (Borja et al. 2007), the Ecological Quality Ratio and the Biological Quality Ratio are each suited to assess greater changes to benthic communities over time (Quintino et al. 2006). These researchers noted that the univariate metrics noted above often displayed as much within-site variability as between-site variability (Quintino et al. 2006). This observation may call for site-specific testing or calibration of indices prior to monitoring. Multivariate characterizations of benthic communities may be calculated using a number of software packages, the most popular of which is Primer 6 (Clarke and Gorley 2006). For example, Primer has been used to identify clusters of similar stations based on macrofauna community composition, and to link community types to suites of environmental variables (e.g., Jarvis et al. 2004; Emu Ltd. 2006; Ware et al. 2010; ESS Group, Inc. 2011; van der Wal et al. 2011).

Beam trawls: Biotic; local scale. Several studies have used beam trawls as an additional method (other than video/photography and grabs) for sampling epifauna (Jarvis et al. 2004; Emu Ltd. 2006; Walker et al. 2009). Beam trawls are typically located in areas of known bottom type, conducted at a constant speed, and for a known transect length. Transects of ~1800 m were deemed adequate for assessing the impacts of windmills on epibenthos in Belgian waters (Degraer et al. 2010). Colonial and sessile epibenthos are usually recorded with a presence/absence metric because individuals may be difficult to quantify (Jarvis et al. 2004).

Optical backscatter sensor/turbidity sensor: Abiotic; local scale. Suspended particulate matter (SPM) can increase from disturbance to the seabed due to construction activities (e.g., cable trenching), and changes to hydrodynamics due to structures on the seafloor (ABPmer Ltd. et al. 2010). Turbidity sensors can be used to measure the concentration of SPM in mg/L at point locations throughout the study area. Studies in the Belgian part of the North Sea used optical backscatter sensors mounted to ADCPs at 0.2 m and 2.0 m above the seafloor at one location in the prospective wind farm field (Van Den Eynde et al. 2010). It should be noted that monitoring for SPM might not be appropriate or necessary for certain type of development (e.g., construction of monopiles) (ABPmer Ltd. et al. 2010).

2.1.2. Post-Construction Monitoring

Monitoring plans need to be designed to take into account the impacts that are anticipated for the type and scale of development. The type and scale of development affect the degree of impact and will be somewhat unique for each development. Most of the studies reviewed adopted a conceptual framework for monitoring, as done by the German Federal Ministry, where similar attributes are monitored for both large-scale effects and small-scale effects (Meibner and Sordyl 2006). Large-scale effects include changes to sediment characteristics, seabed/habitat structure and infaunal communities across the study area. These effects were monitored at least annually using geophysical surveys, underwater video (for supporting the interpretation of the acoustic surveys), and grab samples (for grain size analyses, characterizing species abundance, diversity, dominance structure and community structure). Small-scale effects are changes to sediment characteristics, seabed/habitat structure and infaunal communities at the individual device foundations. These effects were monitored more often (e.g., twice annually) and sampled within a defined radius (e.g., 50 m) of each device. The tools used for small-scale sampling may be the same as for large-scale sampling, but involve a change in technique; for example, video surveys target device foundations, scour protection, and cable routes. In the Dutch offshore wind farm Egmond aan Zee (OWEZ), monitoring at the smallest scales involved setting out trays of manipulated sediment at turbine sites to compare levels of recruitment between the different grain sizes that might be found as a result of turbine construction (Bergman et al. 2008). Beyond matching tools to impacts (which may vary according to development), a vital component to detecting change in monitoring plans involves the design of the sampling scheme and statistical analyses.

Field sampling design

Most studies that reviewed used the results of the baseline survey to structure the field sampling strategy of the subsequent monitoring program. The simplest example is for the Kentish Flats wind farm, where the same baseline sites were re-visited for the monitoring program. Since the sites had been successfully sampled before, they were assured data could be recovered for monitoring purposes (Emu Ltd. 2006). The Cape Wind project used the standard deviation of taxonomic richness measured in the baseline study to generate a curve of effect size which was then used to determine the minimum number of samples needed to detect an effect using t-tests (ESS Group, Inc. 2011). Similarly, the Dutch OWEZ project used power analysis to determine what degree of change to benthic communities would need to occur in order to be detectable (Daan et al. 2009). These are important first steps that help characterize the existing variability in the study area. If natural variability is high, it will be necessary to increase the sample size in order to detect any significant changes over time (Carey and Keough 2002).

The actual locations of sampling stations should be placed with environmental conditions and potential impacts in mind. For example, placement of reference stations should, at the very least, attempt to replicate the substrate type of the impact sites, but also be placed in areas with similar hydrodynamics (Jarvis et al. 2004) and other levels of anthropogenic impact (BSH 2007). With a more sophisticated understanding of the physical environment, stations should be placed to take into account the results of geophysical surveys (i.e., sample all "habitats") and known coastal processes (Walker et al. 2009), such as the direction of currents (Leonhard et al. 2006), and other environmental gradients (Ware et al. 2010). Minimum standards may be applied; The German Environmental Impact Standards dictate that ground-truthing of geophysical data (i.e., grab samples) should not exceed 1 nautical mile spacing (BSH 2007). A monitoring study of the benthic environment following dredged sediment disposal defined control and impact "areas" or zones, where 20 sample locations were selected randomly within each area during each sampling campaign (twice annually for five years) (van der Wal et al. 2011). This enabled the researchers to determine whether or not statistically significant impacts occurred over a wide area.

A consensus among most monitoring programs was that at least three replicate samples should be taken at each sampling station (e.g., Emu Ltd. 2006; BSH 2007; Walker et al. 2009; Ware et al. 2010). When using AMBI score, a common index utilized in monitoring plans associated with the European Water Framework Directive 2000 and Marine Strategy Framework Directive 2008, Muxika et al. (2007a) found that an absolute minimum of two replicates were necessary if at least 0.25 m^2 of area was sampled per site. After two years of monitoring studies in the Belgian part of the North Sea, a proposal was made to reduce the total number of stations sampled in order to increase the amount of replicates per station, from three to five (Degraer et al. 2010). This strategy increases the statistical reliability of the results at each station, but at the cost of spatial coverage of the area.

Statistical design

The first part of a statistical design should acknowledge to what condition the effects of offshore renewable energy impacts are being compared. Essentially, a reference level must be defined and agreed upon before the onset of monitoring in order to ensure success in detecting change. Reference levels can be defined by using existing benchmarks (i.e., presence/absence of endangered spp., toxins), utilize a reference direction (i.e., decrease in seagrass coverage), a threshold in exposure-response relationship (i.e., mathematically-characterized functional relationship), a baseline (i.e., historical condition OR remote/protected area), or normative condition (based on societal needs) (Samhouri et al. 2011). For most of the monitoring programs reviewed, reference conditions were defined using a baseline reference level, through surveys that took place a few months or years before development at the site to create a "historical" baseline, and/or by comparison with a nearby, physically similar but undisturbed environment that was protected from the anthropogenic disturbance under study.

In order to determine what has changed since development, qualitative and/or quantitative approaches may be used. Examples of qualitative approaches are the benthic disturbance-response models for the effects of nutrient enrichment (Pearson and Rosenberg 1978) and the effects of physical disturbance (Rhoads et al. 1978). Users of these models simply compare the observed successional stage, or composition of the benthic community, with the stage/composition along the disturbance gradient specified by the models in order to estimate degree of disturbance or the time since disturbance. Where more quantitative results are desired (i.e., a statistically significant change is detected), univariate and multivariate statistical tools were used in conjunction in many of the studies reviewed. Univariate statistics answer the question “was there a significant difference in the metric after impact?” For example, the monitoring program for the Cape Wind project (discussed in Section X) stated that the benthic community in the area of the subsea cable would be considered “recovered” if there was no significant difference in species richness after construction (ESS Group, Inc. 2011). The statistical technique used in these cases is either one-way ANOVA using “time” as the treatment effect (e.g., Leonhard et al. 2006), or two-way ANOVA using “time”, “site” and their interaction as the effects, as in a Before-After-Control-Impact (BACI) design (e.g., Degraer and Brabant 2009; van der Wal et al. 2011). Multivariate analyses utilize the species composition and community structure of the sample to form clusters of similar samples and visualize them in multivariate space (e.g., clustering, multidimensional scaling), determine if species composition has changed significantly over time or is significantly different among sites (e.g., analysis of similarity), determine which species are most responsible for these differences (e.g., similarity percentages), and which abiotic variables might co-vary and co-occur with distinct benthic communities (e.g., BIO-ENV) (Primer; Clarke and Gorley 2006; Proctor et al. 2003; Emu Ltd. 2006; Ware et al. 2010; van der Wal et al. 2011). Besides the tools available in the Primer statistical package (Clarke and Gorley 2006), other tools such as two-way indicator species analysis and canonical correspondence analysis were utilized to a lesser degree in studies reviewed (e.g., Proctor et al. 2003).

Linking to ecosystem science

Regardless of the suite of tools used, most baseline and monitoring studies assessed by the projet team placed an overwhelming emphasis on establishing biotic-abiotc linkages and/or relationships. By taking an integrated approach, these studies are better able to describe spatial patterns in addition to gaining insight into ecosystem processes. A review of benthic mapping and assessment approaches concluded that substrate maps should not be used solely as proxies for habitat type; map boundaries should be generated from interdisciplinary data sources and tested to ensure that they are ecologically sound (Diaz et al. 2004). The mapping of seabed morphology in Long Island Sound for the purpose of studying artificial reefs and potential wind farms found that biogenic structures were often diagnostic features of the geomorphology, underscoring the importance of abiotic-biotic relationships in defining habitat (Kinney and Flood 2005). Lastly, Diaz et al. (2004) do not endorse a single biological metric for benthic assessment, such as species diversity or richness. Instead, they recommend that indicators of benthic environment status should be chosen for their effectiveness at the study location, for the purpose of the project, and their ability to detect meaningful changes in these contexts.

The Canadian seafloor mapping strategy recognizes these issues and provides a practical example of how projects balancing science, technical/data limitations and stakeholder needs might proceed. In areas with a high percentage of acoustic data coverage and geologic ground-truthing, targeted still photography and video imaging are used to establish relationships between benthic communities and regional geology. This approach relies heavily on multivariate statistics (e.g., cluster analyses, analysis of similarity) to explore and validate these abiotic-biotic relationships. Habitat boundaries are defined by the proportion of the variance in benthic community structure that is explained by different environmental factors (Todd and Kostylev

2011). Where important biogenic habitats have distinct acoustic signatures and known physical constraints on suitable habitat types (e.g., sponge reefs), acoustic signatures are mapped to target these habitats and quickly provide broad-scale data for very cost-effective management and conservation plans (Kostylev and Hannah 2007).

Many baseline and monitoring study plans aspire to assess the ecological function of the environment where development is taking place, but fall short of designing a sampling program to address this goal. For example, the Cape Wind Construction and Operation Plan on seafloor habitat and benthic community monitoring states that the "ecological role of individual taxa" in the benthic community will be incorporated into the review of benthic community composition, but no plan of how to assess this, beyond a description of "successional stage" is provided (ESS Group, Inc. 2011). A solid example of how to accomplish this in practice is provided by Frid (2011), on a 30-year benthic macrofauna dataset. In this study, macrofauna assemblages were scored based on size, trophic role, burrow depth, bioturbation capacity, and longevity. These scores were then translated into ecological functions – carbon cycling, food provision for fish and nutrient cycling/regeneration. Using this method, Frid was able to show that although species composition and density fluctuated over the course of the 30-year dataset, functional redundancy within the community maintained the principle functions present at the beginning of the time series. This type of approach clearly identified how biological changes related to ecosystem changes and would thus lend itself well to an ecosystem-valuation exercise.

After two years of monitoring in the Belgian part of the North Sea to evaluate existing and possible impacts of wind farms, researchers are upgrading the monitoring program "to a level of process understanding" by conducting targeted monitoring (Degraer and Brabant 2009). Targeted monitoring, based on the results of the initial monitoring, will take the form of testing hypotheses that explore cause and effect relationships related to offshore energy development impacts. Testing hypotheses at this stage will feed directly into ecosystem-based management of Belgian waters by helping to predict future impacts, explore how to mitigate these impacts, and provide more generic knowledge of impacts versus site-specific observations (Degraer and Brabant 2009).

2.2. Current U.S. Monitoring Requirements and Standards

In Europe and North America, the few monitoring requirements in place, discussed below, address the physical disturbance and chemical impacts of offshore renewable energy on the benthic environment. At best, these requirements specifically address the composition and integrity of benthic communities. At worst, the requirement of generating an environmental impact statement merely calls attention to the benthic environment as an area of potential impact in a broad sense.

The U.S. Federal Energy and Regulatory Commission (FERC), in the Integrated Licensing Process, requires that an Environmental Assessment contain a description of the existing environment and potential resource impacts that may constitute a major federal action which would affect the quality of the human environment (FERC 2006). Relevant to the benthic environment, the pre-application must contain descriptions and maps of existing geology, topography, and soils, and identify existing fish and aquatic communities, essential fish habitat, along with their spatial and temporal distribution (FERC 2006). FERC does not require or recommend specific methodologies or any duration for monitoring studies. The requirements state that the monitoring study plan must explain the proposed methodology, data collection techniques and schedule, analysis techniques, the duration of the study, and that all of these must be consistent with generally accepted practice in the scientific community (FERC 2006).

2.2.1. Under Current Offshore Renewable Energy Permits

This section summarizes the monitoring plans developed for offshore renewable energy projects in the United States that are currently proposed or under development.

Cape Wind Energy Project, Massachusetts

The seafloor habitat/benthic community monitoring program developed for the Cape Wind project involves both pre- and post-construction monitoring of the subsea cable route. Both monitoring projects will involve characterization of benthic macrofauna community composition, substrate composition, extent of submerged aquatic vegetation, and the frequency of lobsters, crabs and scallops, inside and outside the area of potential impact, using underwater video and grab samples. Post-construction monitoring will occur during the summer for 2 years after cable installation. Five reference stations and five stations along the cable route will be sampled starting 6 months after cable installation. "Recovery" from cable installation disturbance will have occurred when post-construction benthic communities achieve the same level of statistical similarity as the pre-construction benthic communities, and there is no significant difference in species richness (ESS Group, Inc. 2011).

Admiralty Inlet Pilot Tidal Project, Washington

The baseline inventory involves multibeam bathymetry, processed to IHO order 1 navigational standards, side scan sonar surveys, subbottom surveys, grab samples taken "as feasible", and ROV-operated video within 50 meters of the estimated turbine locations. Monitoring studies will take the form of ROV-operated video surveys around the base of each foundation (10 m^2) and along portions of the subsea cable route. During the first year post-construction, ROV-operated video will be used to document benthic habitat conditions and biofouling every 2-3 months. In subsequent years, video surveys will be conducted twice annually (Snohomish PUD 2009b).

Reedsport OPT Wave Park, Oregon

Following an initial Environmental Assessment, where the geology and marine communities of the project area were extensively characterized, fish and invertebrate studies have been proposed to monitor benthic communities (i.e., infauna and epifauna) and species of interest (i.e., Dungeness crab, Salmon). A 2-m beamtrawl will be used to monitor epibenthic invertebrates and flatfish adjacent to the array and at two control sites, three times a year for years 1, 2 and 3. Because of the size of the PowerBuoys and moorings associated with this project, the monitoring of the biofouling communities on the structures is proposed to be qualitative, utilizing SCUBA and ROV-operated video to conduct visual assessments during years 1, 2, and 5. Ceramic plates will also be used to study settlement patterns at three depths and to evaluate the growth of native and non-native biofouling species. For monitoring benthic infauna, a BACI plan will be used to assess the spatial and temporal differences. Grab sampling will occur in June and September of each year 1, 2, and 3 within the array and at two control sites. Statistical analyses of all quantitative benthic monitoring data will include analysis of variance and multivariate analyses such as cluster analysis and multidimensional scaling (FERC 2010).

2.3. Current E.U. Monitoring Requirements and Standards for Offshore Renewable Energy

Countries within the European Union (E.U.) have adopted umbrella regulations for addressing ecological quality for coastal and marine waters: The Water Framework Directive 2000 (WFD; for coastal waters; but also including estuaries, lagoons, lakes and rivers), and the Marine Strategy Framework Directive 2008 (MSFD; for marine waters). These Directives mandate that the current ecological or environmental state of an area be compared with that which would be expected under minimal or sustainable human use, and if determined to be degraded, management action must be taken in order to halt any further degradation and to then move towards raising the status back towards "good". To meet these requirements, the European Commission Joint Research Centre (JRC) and the International Council for Exploration of the Sea (ICES), among several other academic and government institutions, are in the process of standardizing assessment methods for the MSFD (Rees et al. 2007; Borja et al. 2007), indicators (Muxika et al. 2007b; Van Hoey et al. 2010), and seafloor monitoring methods (Rice et al. 2010). Recommendations from these efforts include at least yearly sampling of the benthos using metrics such as average abundance, biomass, species richness, and AMBI index, combined with mapping of geomorphology every 6 years. Seafloor integrity should be assessed using measures such as substrate character, presence of bioengineers, bottom water oxygen, and concentrations of contaminants. For Europe, reference conditions for monitoring and assessment are complicated to derive because un-impacted sites are often difficult to find. The WFD recommends four strategies for defining reference conditions: 1) comparison with existing pristine/un-impacted sites; 2) historical data; 3) modeling; 4) expert judgment. In the case of monitoring for offshore development, comparison with existing un-impacted sites and the use of historical data can both be utilized as reference conditions.

More relevant to offshore development, the Food and Environment Protection Act (FEPA) in the UK ensures that licenses for offshore construction (including renewables) include a pre-construction survey, a during-construction survey, and at least three consecutive annual post-construction surveys (Walker et al. 2009). In Germany, the Seeanlagenverordnung (Offshore Installations Ordinance) mandates that most projects complete an Environmental Impact Assessment and provides information to permit applicants on the scope of investigations required (BSH 2007). Operation-phase monitoring is considered "indispensable" and the Standards for Environmental Impact Assessments outline the minimum requirements for baseline surveys and monitoring (BSH 2007). These standards also dictate the line spacing of geophysical surveys in homogenous versus heterogeneous bottom types (minimum 500 m versus 100% coverage, respectively) (BSH 2007).

3. FISHERIES

This section of the review is focused on monitoring the changes that are expected to occur to fish and fishing activity as a result of offshore renewable energy construction, operation and decommissioning. When the project team considered the range of offshore renewable energy technology types and the existing research on potential impacts (see Task 1.2, Report on

Monitoring the Potential Effects of Offshore Renewable Energy), it was determined that the greatest changes that are also most likely to occur to fish and fisheries are due to disturbance from noise during installation and operation, changes to abundance and distribution caused by a change in habitat, reef effects caused by new habitat, and disturbance or attraction caused by EMF emitted from subsea cables. Blade strikes and pressure gradients are also a concern specific to tidal power devices. In most cases, the device type (i.e., wind, tidal, wave) does not influence the level of impact. The degree and nature of the impact is primarily controlled by the numbers and types of foundations placed on the seafloor. The degree of impact will also be different depending on the nature of the structure and construction method.

Effects can occur from the local level (e.g. around a single device) to the regional level, particularly if migration routes or entire populations are affected. The types of monitoring that will be appropriate for fish and fishing activity will vary greatly, and will depend on factors such as: the type of data required for monitoring; the size of the project and the spatial extent of the monitoring; management considerations such as stock and conservation status; the location of the fish species and the gear used to catch it in the water column; the spatial area that can be covered by static versus mobile gear; the potential for impact; and the marine industry using the monitoring protocols. The fish and shellfish species recognized as important to recreational and commercial fisheries will vary by region, watershed, and even community. The appropriate methods will vary depending on which are most appropriate to monitor the particular species of interest. Below are examples of various types of monitoring that can be used to monitor fish or fishing activity.

3.1. Types of Monitoring, and the Potential Effects they Address

3.1.1. Distribution and Abundance effects

Many of the potential effects to fish relate to a question about secondary effects: will the placement of offshore renewable energy devices have an impact on the abundance, distribution, and species composition of fish within the area? Instead of or in addition to monitoring each potential effect individually, overall changes to distribution and abundance of fish should be monitored. Individual drivers such as habitat disturbance including smothering and turbidity, construction and operational noise, electromagnetic fields (EMF), reef effects, and vessel traffic all could have an effect on abundance and distribution such as through disturbance, reducing/increasing food availability, and increasing predation and competition (Gill 2005).

Determining how changes to the marine environment affect the distribution and abundance of fish species can be done through a number of commonly used fisheries stock assessment methodologies. Stock assessments are conducted to provide fisheries managers with data necessary to manage a fish stock and evaluate changes to the stock, including factors such as population or biomass, age structure, mortality, and growth rate. Monitoring fish abundance is also important to understand the seasonal distribution of species at different life cycles. Typically, at least part of the assessment is conducted through the analysis of existing data. Within the United States, data exist on the distribution and abundance of fish within federal waters through National Marine Fisheries Service (NMFS) stock assessments, conducted on an annual basis. NMFS conducts trawl surveys in each region at randomized locations, and these surveys form the basis of the stock assessment. The trawl data are used to form the fisheries distribution and abundance assessment to meet NEPA (National Environmental Policy Act) requirements. Additionally, some states have their own resource assessment surveys that are used in state waters (e.g. MA, WA, discussed below). In cases where developments have been proposed in states where these data are available, the data on abundance and distribution in state waters supplement the NMFS stock assessment data. Stock assessment data are intended for use on a regional scale. They may be able to provide baseline data for projects but are less useful for assessing change at the scale of an offshore renewable energy project as fish stocks will utilize an area much larger than that of a single offshore renewable energy device or field of devices.

Similarly, within Europe, stock assessments are made based on landings data, discard sampling, and research vessel surveys. These stock assessment data make up at least part of the basis of baseline fisheries data used in Strategic Environmental Assessments. To date, there have been no long-term analyses of entire fish assemblages around decommissioned oil platforms or wind parks published (Erich et al. 2006). Most stock assessments of groundfish species, both in the U.S. and Europe, are done using traditional fish survey methods, usually with an otter trawl. Traditional trawl surveys are limited in that they do not target pelagic species, which are thus underrepresented, and they cannot generally be used in very rocky areas. Trawl surveys need to be conducted at least yearly to be an effective method of stock assessment and thus require considerable investment, particularly of time. The specifics of trawl survey design will vary depending on the needs of the survey, the region, financial and practical considerations, etc. The trawl itself will depend on the type of vessel to be used the species targeted, the bottom type, etc. There are numerous examples of trawl surveys around the United States and the world, each varying slightly in the size and style of the net, the speed and duration of the tow, and other factors. While the most suitable arrangement will vary, what is important is keeping these variables consistent over the duration of the monitoring program. The mesh size in the cod end of a trawl used in survey research should be smaller than that typically used in commercial fishing to retain smaller fish (Pilling et al. 2007). A few representative examples of trawl surveys are presented here:

The Massachusetts Division of Marine Fisheries (DMF) conducts a bi-annual research trawl survey in order to obtain fishery independent data on the distribution, abundance, size and age composition of finfish as well as crustaceans and mollusks. This survey is conducted from a 65 foot boat, towing a 3/4 size North Atlantic type two seam otter trawl at 2.5 knots, equipped with a 6.4mm knotless liner on the cod-end to retain small fish. The survey has been conducted twice a year for the last 32 years in the spring and fall. Sites are selected using a stratified random design using depth strata and a one square mile nautical grid. Massachusetts coastal waters are stratified into geographic zones or strata based on depth and area. Pre-determined trawl locations are assigned in proportion to the area of each stratum and selected randomly within each stratum, with approximately one station selected for every 19 square miles (49 sq km).

The NEAMAP (Northeast Area Monitoring and Assessment Program) trawl survey, coordinated through the Virginia Institute of Marine Science, is a fishery-independent survey program to assist with stock assessments. The NEAMAP surveys are conducted from a 90-foot trawler, using a 400 x 12 cm net with a one-inch (25.4 mm) knotless liner in the cod end. The program conducts two cruises per year, in every spring and fall, sampling approximately 150 stations in 15 regions with each cruise. At each station the net is trawled along the bottom for 20 minutes at a speed of 2.9-3.3 knots (5.4–6.1 km/hr). The NEAMAP protocol uses the same random stratified site selection process as the Massachusetts DMF.

The Washington Department of Fish and Wildlife (WDFW) has conducted a series of bottom trawl surveys in their waters, using chartered fishing or government vessels. The WDFW uses a 400 cm mesh Eastern net with a 30 mm liner in the cod end. The net is fished for 10-20 minutes at each transect, at a speed of 1.5-3 knots. Sampling sites are selected using a stratified-random or stratified-systematic approach based on four depth zones for each region. Additionally, for areas that are too rocky or have a high relief and cannot be trawled, the WDFW uses a video assessment survey. The video assessment survey entails deploying a video camera mounted on a tripod at pre-selected locations of known or suspected rocky habitats. Areas are surveyed out to a depth of 37 m (Palsson et al. 2009).

A guide to global stock assessment produced by CEFAS (CEFAS 2010) evaluates some of the standard techniques for conducting stock assessments. Acoustic surveys are sometimes done in conjunction with trawl surveys, and can provide measures of fluctuation in relative abundance and structure of fish stocks. They describe acoustic techniques as being a relatively cheap and accurate tool for evaluating pelagic fish biomass. Acoustic surveys cannot generally distinguish between species, and thus are not useful for species-specific monitoring, but are useful for measuring biomass and abundance, particularly of pelagic fish that are typically underrepresented in trawl surveys. Split-beam echosounders are recommended, and while the typical frequency used is 38 kHz, the authors recommend using a combination of frequencies to permit more accurate species differentiation. Multi-beam sonar has recently been applied to fisheries acoustics as well, although the use of this as a tool in fisheries is still being established (Pilling et al. 2007).

Other methods exist for monitoring the distribution of commercially fished invertebrate species, and these surveys will be important where these fisheries are economically or culturally significant. Stokesbury and Harris (2006) examined shifts in scallop abundance and distribution in a previously closed area opened to fishing using a BACI (Before-After-Control-Impact) study with two experiments, each with an impact area exposed to scallop fishing and an undisturbed control area. The sites were surveyed using a video survey pyramid deployed from scallop fishing vessels to count observed fishes and macroinvertebrates. Lobster and crab stocks are typically surveyed by means of a ventless trap survey, whereby a standard commercial pot with no escape vents is used. In Western Australia, a subset of the lobsters that are captured are tagged and released to gather data on movement (de Lestang et al. 2011). Quahog and other hard clam species are also surveyed for stock assessments; Mann et al. (2005) used a hydraulic patent tong with a coverage of one square meter to sample for quahogs in the Chesapeake Bay.

Heinig and Tarbox (2000) determined lobster distribution at proposed dredge sites by conducting a quantitative video survey of the bottom for a month. Video surveys were conducted during the day and at night at proposed dredge sites and adjacent to these sites. Survey traps were also fished by commercial lobstermen

To monitor fish distribution and abundance for changes to community structure or hydrodynamic effects around tidal and wave energy devices, acoustic approaches can be used, including sonar, acoustic cameras, and acoustic telemetry, which involves tracking fish tagged with an acoustic transmitter. However, in locations with high sediment loads, fresh and salt water mixing, or air bubbles, detecting small fish using acoustic methods may be difficult (Polagye et al. 2010).

For monitoring fish distribution around a BP oil exploration site in Prudhoe Bay, Alaska, four fyke nets were set in specifically chosen locations (Fechhelm et al. 2004). Fyke nets have also been used in Denmark to investigate the potential effects of electromagnetic fields on fish by analyzing the movements of several species of fish across the cables (DONG Energy 2006); see Section 1.3 for more on this. Fyke nets are much more limited in the area they can sample than trawl nets, as they are stationary and only cover a small area, but can be useful for site-specific studies, or for capturing mobile species either in shallow water or near the sea bed.

3.1.2. Monitoring for Noise Effects

Little is understood about the effects of noise on fish, and the particular impacts are difficult to monitor. It is likely that many species of fish will be able to hear the operational noises from wind turbines, but it is not known whether these sounds will disturb fish, driving them away, or whether fish will acclimate to the sound (Wahlberg and Westerberg 2005; Popper and Hastings 2009). To understand the effects of operational noise, distribution and abundance studies will be most useful.

One study in Norway used an acoustic survey to assess the effects of seismic surveying for oil and gas mapping on pelagic fish. The study was conducted with a Simrad EK 400 echo sounder and a hull-mounted 38 kHz split-beam transducer. Three transects were conducted for pelagic fish, up to 30-50 km away from seismic activity, during and in between the surveying activity. The study found no evidence of short-term effects of seismic activity on herring. Blue whiting and mesopelagic species were found in deeper water at times of surveying than in periods without shooting, indicating a potential scaring effect. The overall density of fish was lower within shooting area than outside of it, but this could not necessarily be attributed to the effect of the noise from seismic surveying. No data on noise levels were provided for this study (Slotte et al. 2004).

Similarly, Engås et al. (1996) studied the effect of seismic surveying for oil and gas on catch rates of cod and haddock. They conducted acoustic and catch surveys before, during, and after a seismic surveying event in an area of 40 square miles around the activity. Acoustic mapping of fish distribution was done with the Simrad EK 500 echo sounder and a hull-mounted 38 kHz split-beam transducer. Standard bottom trawls were undertaken in the study area at various distances from the shooting area, with 60 trawls conducted before the seismic shooting, 65 trawls during the shooting, and 60 trawls five days after the shooting. The hauls lasted for 30 minutes at a towing speed of 1.8 m/sec, and were conducted both during the day and at night. Long line catch surveys were also conducted. The maximum noise level measured was 248.7 dB re 1 μPa at 1 m. The noise from the air guns was about 120 dB above measured ambient noise, and about 60 dB above measured noise from fishing vessels. The study overall found that both the acoustic density and the numbers of fish caught were significantly lower during and after the shooting activity than before it began. The longline catch survey suggested less of an effect, but this was partly because a linear relationship cannot be assumed between the long line catch rate and fish abundance, as catch rate is limited by the number of hooks and the soak time of the line (Engås et al. 1996).

The California Department of Transportation (Caltrans) monitored the effects of pile driving on fish in a pipe installation project for the San Francisco-Oakland Bay Bridge (Caltrans 2001). Pile driving was conducted over a 14-day period, and monitoring was done during eight of those days, including monitoring of various hammer sizes and pile driving with and without sound attenuation. Acoustic measurements found RMS impulse sound pressure levels as high as 196 dB re 1 μPa at 103 meters from the pile, when the largest hammer was used with no sound attenuation. Transects were conducted in the vicinity of the pile driving before, during, and after pile driving using a depth sounder to observe fish schools and changes in fish distribution patterns at various pre-established distances from the pile. No fish were observed to move out of the area during pile driving operations. Bird abundance and activity was also observed before, during, and after pile driving; birds were observed gathering in the area and diving into the water to prey on moribund fish during pile driving. Gull activity was lessened when an air bubble curtain or a fabric barrier system was used along with a small hammer, suggesting that mortality was reduced. Fish that had been killed or stunned by pile driving were collected to assess recovery or determine the cause of mortality. Finally, caged fish were held at various distances from the pile and at various depths, and analyzed for damage. This study found the effects of pile driving were greater when a larger hammer was used. Fish were found with damage to their internal organs as far as 150 meters from the pile, regardless of the use of sound attenuation. Those fish nearest to the pile, 150 m away, suffered the greatest damage (Caltrans 2001).

3.1.3. Monitoring for EMF Effects

Another effect to be monitored is the potential for interactions of marine fauna with electromagnetic fields (EMF), an area even less well understood than noise effects. In order to understand the potential effects of EMF on fish, at-sea measurements of the emitted magnetic and electrical fields will need to be taken. The electromagnetic field will vary with the power generated by the device, so measurements will need to be taken under different conditions. In some cases this can be done with an ROV, but at tidal energy sites, for example, the strength of the tides will make ROV use difficult. There are no existing protocols for EMF measurement of renewable energy devices (Polagye et al. 2010).

One of the few studies on AC cable EMF to date has been the mesocosm study conducted by Gill et al. (2009). This was a controlled study conducted in a shallow, sheltered coastal area similar to many of the areas where wind farms are constructed or projected in the UK. Two mesocosms were studied, one with an electrified cable and one without. The cables were electrified to produce a level of EMF similar to what would be found at the North Hoyle and Burbo Bank wind farms. Acoustic telemetry technology was used to detect real-time movements of individually identifiable elasmobranchs. Fine scale analyses of individual fish movements and their distance from the cable was conducted, and found that the elasmobranchs did respond to the presence of EMF, but their responses were not predictable and did not always occur (Gill et al. 2009). In general, in situ studies may illuminate some of the potential effects of EMF, but these are difficult to conduct and can be inconclusive (Polagye et al. 2010).

Westerberg and Lagenfelt (2008) conducted a study of the effect of EMF from a subsea cable on eels by catching and tagging eels with acoustic tags, and then releasing the eels 7 km from the cable. Four transects were conducted, two on either side of the cable, with fixed acoustic receivers over the course of three weeks. Distance traveled and swimming speed were analyzed for each eel, and the study found that eels slowed down around the AC cable, although most did pass over the cable, and thus it was not an obstruction to migration (Westerberg and Lagenfelt 2008).

A survey was conducted on the effects of EMF and noise emitted from a gas pipeline in Nova Scotia on snow crab and lobster (Martec Ltd. 2004). Acoustic surveys conducted in the vicinity of the pipeline found a low frequency sound was being emitted that was within the hearing range of lobsters. An electromagnetic survey indicated only a very narrow electrical field 2-3 meters wide on either side of the pipeline, with a field strength up to 1/3 the strength of earth's background magnetic field. The EMF survey was conducted by towing a 10 m length of PVC pipe containing magnetometers and electric-field sensor pairs back and forth over the pipeline. A tripod hydrophone was mounted at 25 different locations at varying distances from the pipeline to characterize the sound emitted from the pipeline. A trap survey was conducted, with lobster traps with their escape hatches shut to retain smaller, sub-legal lobsters set near to the pipeline, and at two reference sites at least two kilometers from the pipeline in areas where fishermen felt the benthic habitat was similar to that of the pipeline area. The catch survey found no statistically significant difference in catches between the pipeline and two reference sites (Martec Ltd. 2004). To date, most studies of the effects of EMF have been related to a single source (e.g. a single cable). ORED are likely to have multiple cables, and thus multiple sources for EMF; little monitoring has focused on the potential effects to fish species under these circumstances.

3.1.4. Monitoring for Strikes or Entrainment

Acoustic monitoring can be used around tidal energy turbines to determine whether fish are interacting with the turbines, including swimming through the turbine or getting struck by the blades. Acoustic methods appropriate for near-field monitoring of devices include split-beam and multi-beam sonar, and acoustic cameras. However, acoustic methods will not work well near the surface or where strong currents exist because of interference from turbulence and waves. Acoustic tags may be used on fish in certain semi-enclosed environments to determine behavioral changes including avoidance or attraction. Because of the level of tagging that would be needed and the density of receivers required, this approach is probably prohibitive for a demonstration-scale project. This approach may also be difficult in an open-ocean environment, where the rate of tag return may be low. Verdant Power used active acoustic monitoring for their East River project, and found the cost of doing so to be very high, while the results were inconclusive (see Section 3.2.1 for more information). Other monitoring that can be used to detect blade strikes include optical cameras and specialized netting (Polagye et al. 2010).

A study at the European Marine Energy Center (EMEC) test site of an OpenHydro tidal turbine used video surveys of the turbine to assess interactions with fish. The fish were found to leave the turbine area as soon as the tidal velocity increases and the turbine started running (Snohomish County Public Utility District [PUD] 2009a).

3.1.5. Monitoring for Reef Effects

The installation of an offshore renewable energy device places a new large structure with a hard surface in the water, and it is assumed these devices will cause reef effects. Fish are likely to be attracted to any devices placed in the water. This has been demonstrated with existing wind farms (e.g. DONG Energy 2006). Benthic invertebrates will colonize the structures, providing food for fish; these structures also provide shelter for smaller species or juveniles, and may also attract larger fish coming to prey on those smaller fish. Changes to fish assemblages and density around the devices should be monitored to determine reef effects. Traditional fish catch study techniques usually involve a trawl survey (see Section 3.1.1 above), which is difficult or impossible around a field of offshore renewable energy devices. However, surveys of the devices themselves are important to determine potential aggregation effects. Unlike the literature on offshore renewable energy, the literature on the association of fish with oil and gas platforms is rich. A number of surveys have been conducted over the years to monitor for aggregation or reef effects at various offshore structures. Section 3.3 provides specifics on monitoring of existing offshore renewable energy projects.

Rademacher and Render (2003) conducted a pilot study to develop a survey design to assess fish aggregation around oil and gas platforms in the Gulf of Mexico. They conducted video experiments around eight oil platforms located in varying water depths. Video was taken with both a four-camera stationary video array and a pan-and-tilt camera system in order to provide a nearly 360-degree view. An ROV with a video camera was used in addition to capture species far inside the confines of the platform. Another survey used a fisheries acoustic system along with a video camera in order to view the area being ensonified by the fisheries acoustic system and to compare the results of the video survey with the acoustic survey. The authors concluded that both the ROV and the four-camera system were necessary to adequately sample both inside and outside of the platform, as there were different species assemblages inside and out. They suggest that SCUBA transect studies should also be included in a survey methodology of oil and gas platforms, as divers can easily get within the confines of the structure. The data collected by divers can then be compared with the video data. They also recommend protocols to quantify data collected by ROV; they recommend either holding the ROV stationary at a set depth, or using a transect method with the ROV (Rademacher and Render 2003). The necessity of sampling inside of a structure will depend on the particular offshore renewable energy device; wind turbines mounted on tripods may require this level of monitoring, while other devices likely will not.

Page et al. (2006) used photographic sampling at offshore oil and gas platforms to look at aggregations of invertebrates on the platform structures. Distribution and abundance of invertebrates was measured by divers photographing a single quadrat located inside and outside the four corner support legs and at four randomly selected conductor pipes at various depths, photographing a total of 128 quadrats per platform. Love et al. (1999) used a submarine to survey fish aggregations around mussel mounds formed at the base of oil and gas platforms. They surveyed at a speed of 0.5 knots, and at 1 m above the bottom. Researchers made observations, and filmed with a camera. In a separate study, Love et al. (1994) conducted surveys with a camera mounted on an ROV at three depth intervals on the oil platform. Photographs were taken along a transect line in a random direction both at night and during the day. They also conducted diver surveys, and fishes were recorded with video. Fish tagging studies were also conducted. Love and York (2005) monitored fish assemblages associated with an oil and gas pipeline in the Santa Barbara Channel. The surveyed the pipeline and the adjacent seafloor using a 4.6 m submersible traveling at .5 knots (0.9 km/hr). Each transect was fifteen minutes long and conducted only during daylight hours. Researchers made observations of aggregations from the submersible, and an externally-mounted video camera filmed what the observers were viewing.

Fabi et al. (2004) surveyed fish abundance and distribution at oil and gas platforms using 500 m long trammel nets with a 72 mm inner mesh and a 400 mm outer mesh. Thirty-five samples were taken at each site over the course of a month. This study had two sites within 50 m of the platforms, and two control sites. Passive trammel gears were used at this site as opposed to trawls and other active gears because active gears are difficult to tow around platforms. However, as the authors noted, the limited height of the trammel net may undersample fishes, especially pelagic fishes (Fabi et al. 2004).

Studies of red snapper fidelity at oil platforms in the Gulf of Mexico fit the fish with acoustic pingers, and placed acoustic receivers at seven platforms. Data were downloaded monthly over seven months (Peabody and Wilson 2006). Thorne (1994) notes the potential utility of remote acoustic sampling for surveying artificial reefs. He argues that fixed acoustic surveys can acquire better spatial and temporal data and are more cost effective than traditional trawl surveys. One acoustic methodology evaluating reef effects of oil and gas platforms in the Gulf of Mexico used dual beam hydroacoustic surveys with three stationary arrays of four transducers on the platforms. Acoustic data were collected during four two-hour intervals at different times of day. A total of thirteen platforms were surveyed with this method. A mobile acoustic survey was also conducted at a nearby reef using a tow fish. Additionally, video and visual data were collected using an ROV deployed from surface to bottom, stopping every 10 m for 5 minutes (Wilson et al. 2006; Stanley and Wilson 2003). The authors note the importance of using a combination of both hydroacoustic and visual survey techniques to study fish assemblages on artificial structures (Stanley and Wilson 2003); again, hydroacoustic surveys cannot identify fish to the species level, so visual surveys will be needed in addition in order to determine species-specific and community level changes.

Surveys of aggregation have taken place at the Flower Garden Banks National Marine Sanctuary since the 1980s. Fish surveys are stationary, conducted by visual census using SCUBA. Surveys are conducted throughout the day, with all fish observed within 5 minutes counted, and additional time used to estimate abundance. Sea urchin and lobster surveys are also conducted at night along 100 meter transects, with a total of 400 square meters surveyed each year (MMS 2008b). A study of Fish Aggregation Devices (FADs) in the Western Mediterranean by Addis et al. (2006) used visual and video surveys by SCUBA divers conducted on a monthly or twice-monthly basis to determine fish assemblages around the FADs. A number of studies have used a purse seine net to count fish around the FADs (Addis et al. 2006).

One study used the Lysekil research site for wave energy devices off the coast of Sweden to study colonization and reef effects. The foundations of some of the wave energy devices were constructed with holes to attract fish and crustaceans seeking shelter in the holes. Visual surveys were made by SCUBA of the wave power foundations installed to determine whether those with holes attracted more fish and crustaceans than those without (control sites). The results did not find any difference between foundation types for fish aggregation, but the holes were used by crabs (Langhamer and Wilhelmsson 2009).

3.2. Current U.S. Monitoring Requirements and Standards

Few requirements exist currently for the monitoring of fisheries resources for offshore renewable energy development or any other offshore development. Projects affecting Essential Fisheries Habitat (EFH) may require an EFH Assessment, but this differs from fishery resource monitoring in that it is the habitat being monitored, although the federal agencies can require fish to be monitored as part of an EFH assessment. Within the United States, monitoring is generally required for Threatened and Endangered Species where applicable under the Endangered Species Act, but as this literature review focuses on fisheries resources, these species are not being directly targeted.

3.2.1. Under Current Offshore Renewable Energy Permits

Cape Wind Energy Project, Massachusetts

The Cape Wind Environmental Impact Statement (EIS) was not required to use site-specific information (although site-specific data was requested by NMFS), and thus used existing data for assessing fish abundance and distribution in the area of the proposed wind farm. They characterized fish resources using data from the Massachusetts Division of Marine Fisheries bi-annual research trawl survey, and from the National Marine Fisheries Service bi-annual research trawl survey. These trawl surveys both employ an otter trawl. Vessel Trip Reports (VTR) data were also used to gain insight into the geographical distribution of fish catches within the area (MMS 2008a). Shellfish and benthic organisms were sampled along the proposed cabling route in order to sample these species that may be affected during the cable-laying process (MMS 2008a).

Admiralty Inlet Tidal Project, Washington

In situ baseline studies at the tidal energy pilot project site in Admiralty Inlet included using existing trawl survey data from the Washington Department of Fish and Wildlife, hydroacoustic sampling in the area of the turbine, and conducting fisheries sampling using a beach seine. Video assessment surveys have also been conducted in the area and can be used for baseline data. Post installation monitoring planned for the pilot project includes remote sensing equipment to detect marine species near the turbines. They will have a multi-beam acoustic camera placed on the foundation of one turbine and aimed at rotor face to provide data on the movement patterns, behavior, and relative abundance of fish and marine mammals, as well as providing some data on length and shape for targets. The data will be transmitted to shore via subsea cable. They will also employ underwater digital video camera and automatic camera triggering system for species identification of organisms approaching the turbine (Snohomish County PUD 2009).

Verdant Power Roosevelt Island Tidal Energy Project, New York

The Verdant Power Roosevelt Island Tidal Energy Project in New York City's East River used fixed and mobile hydroacoustic studies to assess fish abundance. The fixed hydroacoustic surveys used an array of 24 Biosonic split-beam acoustic transducers in fixed arrays to gather information on fish spatial distributions and abundance as well as provide fish behavior by tracking a fish's swimming location and direction. They employed twelve and then 24 transducers 24 hours a day, 7 days a week for 10 months. The fixed hydroacoustic surveys did not reveal any results and were abandoned, in part because of the difficulty in maintaining the equipment. The mobile hydroacoustic surveys were conducted four times prior to installation, and then post-deployment on a monthly basis for six months. They conducted multiple transects around the project area to observe fish presence, abundance and size distributions. Because the data from the mobile surveys is not species-specific, it did not provide useful data on fish distributions pre- and post-installation. Trawl sampling was attempted at this site, but was abandoned due to safety considerations due to hazardous sampling conditions caused by debris and swift currents. The Verdant project also employed a DIDSON system that uses high definition sonar to produce near-video quality graphic displays. The results showed some avoidance behavior, but the data set was too small for any conclusive results. The DIDSON system was found to be very useful to view turbine and fish interactions at the micro-level, particularly where the water was too turbid for traditional video monitoring. A report on the monitoring activity concluded that, at least in this particular location, the DIDSON system was very effective but only at a distance of less than 15 m to maintain appropriate resolution, and that it should not be continuously deployed because siltation and biofouling necessitated regular servicing (Verdant Power 2010).

Maine Tidal Energy Project, Maine

In anticipation of developing tidal energy projects in the state of Maine, the Maine Tidal Power Initiative has been deploying hydroacoustic surveys in tidal regions at multiple locations throughout the state to collect baseline data at both sites where a deployment is anticipated and at control sites. These data are being used to determine how tidal energy devices may impact the movement and migration of species. Surveys were conducted at the project site and a control site before deployment and during a test deployment of the device. Low-frequency SIMRAD single-beam echosounders were used to look at fish distribution throughout the entire water column, and the higher-frequency Dual-Frequency Identification Sonar (DIDSON) system, an acoustic imaging system, was used to look at the top 10 m of the water column to aid in species identification. Acoustic surveys were conducted from a 36-foot fishing vessel. To verify acoustic surveys and determine the species present, tows were conducted with a 3.5 x 3.05 m framed net, with tows lasting 30 to 45 minutes each. The results of the acoustic study indicated at what depth in the water column various species were likely to be at the project site, to determine which were most likely to interact with the device. The study authors note that the time needed to analyze the volume of data collected by acoustic studies can slow the process of deployment of the device (Zydlewski et al. 2010).

Other Monitoring Suggestions

Suggestions for the monitoring of wave energy devices were developed at a workshop on wave energy held in Oregon in 2007 (Boehlert et al. 2008). The findings of the workshop were that wave energy devices should be monitored with video and diver surveys, perhaps as often as monthly, to determine the aggregation effect the devices may have. The effect of the devices on dungeoness crab, an important fishery to the Oregon coast, should also be monitored. Fish tagging studies should also be conducted to determine the residence time of fishes in the vicinity of a wave energy complex, including whether fishes chose to remain near the buoys, and/or if the facilities disrupt normal migration patterns. Changes in fish behavior near the devices could also be monitored using telemetry procedures (Boehlert et al. 2008).

A suggested protocol for monitoring the effects of tidal energy devices is to identify and monitor specific indicator species to identify changes from the cumulative effects of tidal devices (or any other offshore renewable energy device). The appropriate indicator species would be site-specific (Polagye et al. 2010). In general, the BACI (Before-After-Control-Impact) and associated approaches should be considered to find effects, although finding suitable control sites can be difficult (Polagye et al. 2010).

The findings of a workshop on the effects of tidal energy concluded that a minimum of one year of baseline data should be collected on fish in an area where a tidal device is to be installed, particularly to determine whether migratory fish use the area. The monitoring protocols would likely use a combination of hydroacoustic surveys with net sampling and acoustic telemetry (Polagye et al. 2010). Monitoring the effects from tidal energy devices has the additional challenge of conducting surveys during periods of rapid currents when the turbines are in operation (Polagye et al. 2010).

3.2.2. Other Offshore Marine Construction

Dredging

In 2001, MMS developed a series of monitoring protocols to evaluate the impacts of dredging on the marine environment. The protocols related to fish were designed to understand the trophic relationships between fish species and benthic species, and the impact to fish from the loss of certain benthic species in the dredging process. Sampling should be conducted at multiple locations that were physically similar before dredging to establish multiple controls, and sampling should take place on multiple days. They recommend the Beyond BACI sampling design, in which multiple control sites are selected to minimize the chance that observed changes are due to natural differences between sites. Sampling should also be done both in daytime and at night to account for diurnal variation. The protocols call for a pre-dredge survey just before dredging, a survey one year post-dredging, and then surveys every two years after that until year seven. If there are not enough data for sampling stratification, then a baseline survey may be needed as well. Sampling should be done in the same season pre- and post-dredging (MMS 2001).

The monitoring protocols recommend that all fish species be sampled, but numerically dominant and commercially and recreationally important species should be given special attention. The fish species could be analyzed for stomach content to establish the relationship with benthic species. These particular protocols were designed to assess trophic transfer from the benthic community to fish populations, rather than assess changes in the fish community. For fish sampling, consistency in trawl type is important, as is trawling speed. According to NMFS, 3.5 knots (6.5 km/hr) is the ideal trawling speed for fisheries sampling. The same type of net and vessels of similar size and horsepower should be used throughout the monitoring effort. Sonar or video monitoring can also be used to assess the sampling ability of the net (MMS 2001).

Liquid Natural Gas

The Neptune LNG EIS for Massachusetts used primarily existing data to assess the abundance and distribution of fish species in the project area. The study analyzed the Massachusetts DMF and NMFS trawl data to characterize fish abundance in the area. Densities of commercially important species were also projected using data on the CPUE (catch per unit effort) of vessels fishing in the area. The MARMAP and ECOMON databases were analyzed to estimate the abundance of eggs and larvae from fish species. The project also conducted benthic surveys of scallop and lobster populations in the proposed area. This was done using sediment profile imaging and benthic video surveys to characterize benthic habitat and benthic and demersal species. Video surveys were conducted using a video tow sled, surveying 128 transects of 500 feet each (U.S. Coast Guard 2006). The Northeast Gateway LNG project, also in Massachusetts, used a similar methodology and did not use any site-specific information.

Oil and gas

Studies of fish distribution and abundance were conducted in the Beaufort Sea in Alaska to provide baseline data for oil and gas exploration in the area, and to make recommendations for future monitoring. The study employed bottom trawl and midwater trawl surveys targeting different sections of the water column, using different sampling gears, and following different sampling strategies and analyses. Demersal fish were sampled using standard bottom trawl gear and methods. Pelagic fish were sampled using hyrdoacoustics and midwater net tows. Bottom trawling was done over 17 days from a 155-foot vessel using two net reels, towed at a speed of three knots for fifteen minutes. A stratified sampling plan with a random start location was used, and samples were divided among various depth strata. Seven acoustic surveys were conducted, each spaced one nautical mile apart. Acoustic data were also collected during midwater trawl along transect lines, during bottom the trawl survey, and opportunistically after daytime survey operations had ended (Logerwell and Rand 2008).

3.3. Current E.U. Monitoring Requirements and Standards for Offshore Renewable Energy

Denmark

The pre- and post-construction monitoring conducted at the Horns Rev and Nysted wind farms in Denmark included monitoring fish abundance and distribution around the wind farms, particularly to assess the effect of the introduction of stone habitat into the area, monitoring for behavioral changes from fish species around the power cables from EMF, and monitoring specifically the effect of the wind farm on the distribution and abundance of sand eels. The studies followed a BACI (Before After Control Impact) methodology (DONG Energy 2006).

Abundance and species distribution were assessed through catch surveys using both trawling and gillnets both inside and outside the wind farm. No significant differences were found between the control area and the wind farm, but post-construction surveys were carried out shortly after the introduction of new, hard substrate habitat and therefore it may have been too early to demonstrate an effect. Hydroacoustic surveys were also conducted using a SIMRAD EK60 echo sounder and a split beam transducer towed from a vessel traveling along transects at a speed of 1-3 knots. Each site was sampled twice, in daylight and in darkness. Hydroacoustic surveys cannot distinguish between species, but can determine the difference between those fish with a swim bladder and those without. They are useful for assessing the abundance of small pelagic fish (DONG Energy 2006).

Sand eels in the vicinity of the turbines were assessed using a modified scallop dredge to sample sand eels along with sediment composition. Five replicates were made at each location, with each haul lasting ten minutes (DONG Energy 2006).

Fish behavior surveys were conducted at the Nysted wind farm only to monitor the effects of electromagnetic fields (EMF) generated by the power cables. Two types of pound nets (one bi-directional and two quadric-directional) were set up on either side of the cable. These nets were designed to detect the direction of migration of fish, and the number crossing the cable. A CT probe was placed between the pound nets to log direction and velocity of currents to differentiate this effect from the effects of EMF. A related study monitored the migration direction of eels through a mark/recapture study; eels caught in the pound nets were marked and released at least 400 m from the cable, and the catches reported by fishermen. The EMF study was conducted periodically over a four year period. This study suffered from many problems in the sampling and analysis phases. There was no baseline data collected, EMF around the cables was not measured directly, and the nets were relatively far from the cable route, making it difficult to detect any effect of the cables (DONG Energy 2006).

To investigate fouling and reef effects at the Nysted wind farm, divers used underwater video recording and photography along survey tracks on the foundations of seven turbines and on the transformer platform. Foundations were selected to represent different depths and locations within the wind farm. While this study was primarily to describe epifauna and macroalgae on the structures, the presence fish and some larger invertebrates, such as crabs and shrimp, was also described (Birklund and Petersen 2004).

Sweden

Wilhelmsson et al. (2006) surveyed two different wind farms in Sweden for fish abundance, estimating fish abundance and benthic composition by visual SCUBA census, covering 72 transects. All transects were ten meters long and one meter wide, and were conducted during daylight hours. The authors sampled the seabed 1-5 m from the turbines and 20 m from the turbines, each on four sides of turbine. Stationary individual fish, small groups, fish under rocks, and schools of pelagic fish were all counted or estimated by the diver. Observations were made of covering organisms and substrata on the fish transects, and proportions of different bottom types were estimated.

United Kingdom

Monitoring at the Barrow Offshore Wind Farm in the UK involved pre- and post-construction surveys of fish abundance and distribution in the area of the wind farm. Surveys were conducted in the fall to target the autumn flatfish and shellfish fisheries, in the winter to target the winter groundfish fishery, and in the spring to capture the spawning season for most species. Three pre-construction surveys were undertaken with both a beam and otter trawl, and post-construction surveys were conducted at the same times of year. The beam trawl was useful for sampling small fish that spend the majority of their time on the seabed, including juveniles, while the otter trawl was more useful for catching species of a commercial size. The beam trawl was conducted at seven sites, with two reference sites, one along the cable path, and the rest within the area of the wind farm. Sampling with the otter trawl was done along six trawl routes intersecting the lines of the turbines. Sampling with both methods was done post-construction inside of the turbines and at a reference site (Barrow Offshore Wind Ltd. 2009).

Similarly, at the Gunfleet Sands site, pre-construction surveys included sampling by otter trawl in spring, summer, and fall, supplemented by sampling with a beam trawl in the summer to target smaller species and juveniles that might not have been captured in the otter trawl. Five surveys were conducted within the project area, and four outside of it at reference areas, including one along the cable route (RPS Planning and Development 2008).

Monitoring of the North Hoyle Wind Farm in the UK used existing trawl survey data conducted by CEFAS as baseline data on fish abundance and distribution in the project area. The surveys involve a 4 m beam trawl with a 40 mm cod end liner towed at 4 knots for 30 minutes, covering 2 nm per tow. The trawl is fished annually in the fall only during daylight, and there are 34 stations consistently fished. This trawl survey is conducted several kilometers from the North Hoyle site. After the wind farm was constructed, monitoring in and around the wind farm was conducted with a 2 m beam trawl at 22 selected locations. This trawl is not ideal for catching demersal fish and is more suited for epibenthic fish and invertebrates. Analysis showed an increase in the numbers of fish at each trawl station during the years the survey was conducted. This could not be attributed to the wind farm, however, because the increase was found at sites both inside of and far removed from the wind farm. Overall, beam trawl monitoring data did not provide sufficient information to investigate fish aggregation around turbines. Visual monitoring showed gadoid species were feeding off colonized fauna on turbines, and there was anecdotal evidence from fishermen that elasmobranchs were captured within the wind farm, but none were taken in the survey trawl (NWP Offshore Ltd. 2008).

At the North Hoyle wind farm, hydrophones were hung from a buoy at 5 m and 10 m depths from a vessel. The hydrophones were drifting 100 m from the vessel. Measurements were taken during construction through transects over the course of two days. Seventy-five percent of measurements were above 90 dBht, or the level above which significant avoidance reactions are expected to occur. Operational noise was very low, and no evidence was found that animals might avoid the area. The wind farm area found to be about 2 dB noisier for fish and no noisier for marine mammals than the surrounding area (NWP Offshore Ltd. 2008).

A survey by the CEFAS (Centre for Environment, Fisheries, and Aquaculture Science) in the UK of FEPA (Food and Environmental Protection Act, UK) licenses issued in the UK found requirements for fish monitoring have included fish surveys to investigate distribution and abundance (particularly related to EMF and electromagnetically-sensitive species) and surveys inside and outside the wind farm to investigate aggregation effects. Some of these projects have commissioned new data for their license, and some have not. Some have done broad-scale surveys, while others have been more targeted (CEFAS 2010). Current requirements for monitoring for noise include monitoring carried out each year (pre-construction, construction, three years of post-construction monitoring), and making measurements at a variety of locations (adjacent to turbines, between turbines, within array, outside of array at varying distances). The noise measurements taken should reflect differences in sediment type, water depth, and foundation/tower type. They have also required the appointment of a Fisheries Liaison Officer and a Fisheries Liaison Representative who, among other tasks, can meet with local fishermen and determine what effects to fishing activity the construction and operation of the wind farm may be having (CEFAS 2010).

Some issues that CEFAS (2010) identified with the data that have been used include: using short data sets do not allow for clear distinction between effects of construction/wind farm and natural variation in fish distribution and abundance; no review of how findings of surveys relate to construction activities; and sometimes inappropriate gears have been used (e.g. beam trawls to survey pelagic fish).

CEFAS has developed recommended standards for monitoring fish around wind farms. For baseline surveys they recommend surveys in the development area and in a suitable reference area for the characterization and identification of fish fauna. For project and reference areas larger than 100 km sq, a minimum of 30 trawls each should be used. A minimum of 20 trawls can be used when a beam trawl is used. If the planning and reference areas are less than 100 km sq, a minimum of 20 trawls can be used, and 15 trawls are sufficient with a beam trawl. Pre-construction surveys should be done twice a year, in spring and fall, and there should be at least 2 complete seasonal cycles before the start of construction. They suggest that monitoring should occur at least once a year in the construction phase, and in the first, third, and fifth years of operational phase (CEFAS 2004).

The guidelines suggest that tows of commercial gear should be 30-60 minutes in duration and all tows should be of similar duration. Tows with a 2 m beam trawl or shrimp trawl should be 5-15 minutes. The use of small trawls for juveniles should be conducted either in conjunction with the commercial trawl or with a study of benthic species. There should be a minimum of five tows conducted in the wind farm area and preferably more depending on the size of the area. At least three surveys post-construction should be required (CEFAS 2004).

CEFAS also recommends installation-based monitoring at two installations using set nets, taking place a minimum of six days per year, with three deployments each in the spring and fall lasting for 1-2 days each. They recommend a net length of about 190 m. For a sampling strategy, a random station grid is recommended over a fixed grid. Sampling should be carried out at the same time each year, and should only take place between sunrise and sunset. If trawling is not possible, fixed nets should be used between turbines (CEFAS 2004).

Netherlands

The Dutch government developed a series of ongoing monitoring studies for offshore wind energy projects in their country, including baseline studies and monitoring for both demersal and pelagic fish. The protocols for monitoring demersal fish call for conducting studies for two weeks, twice a year, in the wind farm and in three reference areas. The plan calls for sampling at 40 stations, with hauls made along depth contours to minimize variation by depth. Their protocols use two nets fished simultaneously from 6 m beam trawls – one is a 40 mm net, and the other is a 20 mm net to be able to take larger and smaller fish (Grift and Tien 2003). The protocols for studying pelagic fish also call for sampling for two weeks twice a year. These studies call for using a Simrad EK60 echosounder and also conducting reference trawls with a semi-pelagic trawl for two surveys. Their studies conduct high spatial resolution sampling along transects 8-10 km in length in the project area and two reference sites, as well as conducting surveys of low spatial resolution elsewhere, as pelagic fish tend to have patchy distributions (Grift et al. 2003).

These monitoring protocols have been applied to studying the Egmond aan Zee Windfarm in the Netherlands, where post-construction data were collected in 2007, and will be collected again in 2011 to be compared with baseline data from 2003 and 2004. Preliminary results from the demersal fish studies, comparing the first year of post-construction data with the baseline data, found an increase in all fish species caught during both summer and winter months. This increase was found for both the wind farm area and all the reference areas in the summer, and for two of the reference areas only during the winter months. Catch per unit effort (CPUE) also increased for all sites during the summer, but not during the winter. Because the increases in biomass overall were for all areas, they were not attributed to the wind farm. However, when studying certain fish at the species level, it was found that the CPUE of certain species had either increased or decreased in the wind farm area, but not in the reference area. These effects could generally be attributed to the presence of the wind farm, but not specifically to either the construction activity or the presence of the turbines (Hille Ris Lambers and Hofstede 2009).

Belgium

Monitoring has taken place in Belgium since 2005 at three locations where leases were provided to build wind farms. As of 2009, there were six turbines with gravity-based foundations in place, and ongoing construction on 55 additional monopile turbines. These studies used a BACI design with a reference and impact study site. Studies of demersal fish have been conducted with an 8 m beam trawl with a mesh size of 22 mm, towed for 15 minutes at 4 knots (7.4 km/hr). Samples have been taken twice a year, in three different years. Studies of fish in the area found fish densities and biomass were higher in reference areas than in the wind farm area for one site, and were higher in the wind farm site than reference areas for another, indicating that this observation was due to natural variability. There were some species-specific differences at one wind farm site, with densities of one species being higher and another being lower within the impact site compared with the reference site; these differences could possibly be attributed to a change in food resources or competition resulting from reef effects from the turbines. At the time these data were collected, there were only six turbines, and they had only been in the water for a short time; thus it may take more time to be able to detect any effects (Derweduwen et al. 2010).

To investigate potential reef effects on the turbines, nine surveys were conducted by SCUBA divers over a three month period on a single turbine to estimate the numbers and sizes of pouting (*Trisopterus luscus*) around the structures. Line fishing and gillnet fishing were also conducted around the turbines throughout the year to estimate CPUE as a measure of abundance. They found pouting densities were highly enhanced near the turbines, and stomach analyses found they were eating benthic fauna found on the structures (Reubens et al. 2010).

Germany

Germany's monitoring standards require a full two years of baseline data for any survey conducted as part of offshore renewable energy monitoring. The baseline data remain valid for two years after collection; if construction has not begun at this time, additional baseline data will need to be collected. Post-construction data must be collected during the operational phase for at least three years, and sometimes up to five years. Having a reference area is required as part of any monitoring protocol. The reference area for fish should be in the vicinity of the project area but free from any influence of the construction activities, located at a minimum of 1 km from the wind farm (Bundesamt für Seeschifffahrt und Hydrographie [BSH] 2007).

Fish surveys and monitoring in Germany involve the use of beam and/or bottom trawls. If these methods cannot be used, multimesh set net surveys may be used as an alternative. The surveys must also include measures on depth, salinity, temperature, and oxygen. For both the baseline and post-construction surveys, there should be a minimum of 30 hauls conducted where the project and reference areas are larger than 100 square kilometers. If a beam trawl is being used instead of a bottom trawl, 20 hauls is considered sufficient. If the reference and planning areas are smaller than 100 square kilometers, at least 20 bottom trawl or 15 beam trawl surveys are required. The baseline data require a single survey in spring or fall as a preliminary investigation, followed by surveys twice a year in spring and fall for two years for the status assessment as part of developing a baseline. During the operational phase, monitoring is required once a year in the fall and additional monitoring during the spring is recommended. These surveys should be conducted for one year during the construction phase, and in the first, third, and fifth years of the operational phase. Additionally, during the operational phase, installation-based monitoring is required to be carried out at two turbines using multimesh set nets. The net surveys are required to be deployed 3 times each in spring and fall, for 1-2 days each. Survey equipment differs by region; surveys in the North Sea required a 6-8 m beam trawl, or an otter trawl in combination with a 3 m beam trawl. In the Baltic Sea, an otter trawl with a cod-end mesh size of 38 mm is specified. The hauls should last for 30 minutes, and be towed at a speed of 3-4 knots. Sampling should be carried out at the same time each year, and only during daytime (Bundesamt für Seeschifffahrt und Hydrographie [BSH] 2007). An ongoing survey of Germany's alpha ventus wind farm is also using hydroacoustic surveys to study mesoscale distribution of fish in the area, including species composition and length distributions. They are also using imaging sonar to survey fish in close vicinity to the turbines, and deploying fixed hydroacoustic systems for long-term surveying of fish in proximity to a turbine, within the wind farm, and within a reference area (Krägefsky 2010).

3.4. MONITORING OF FISHING ACTIVITY

There are no standard methodologies for monitoring fishing activity or changes to fishing activity. Within the United States, a few different types of data are collected from commercial and recreational fishing activity that can be used to describe fishing, and can be analyzed to compare changes. These include, at the level of federal fisheries, Vessel Trip Reports (VTR), which are a report filled out by fishermen; Vessel Monitoring Systems (VMS), a device mounted on board some fishing vessels that tracks their movements; fisheries observer reports; and landings data. These data are limited in that they are subject to confidentiality requirements and they do not account for activity by vessels without a federal permit (involved solely in state fisheries such as lobster). VTR data does not provide much information on spatial use, as fishermen are required only to indicate the location where they began fishing. Studies of the spatial aspects of fishing activity in Europe and elsewhere also typically employ existing data, rather than collecting new data on fishing activity.

To characterize fishing activity within the proposed area of development for the Cape Wind project, the EIS authors used VTR data from NMFS to gain insight into the geographic distribution of fishing activity (MMS 2008a). VTR data were also used from party and charter boats to characterize recreational fishing activity. Additional spatial information on fishing activity was obtained through interviewing recreational and commercial fishermen, shellfish officers, harbormasters, bait and tackle shop employees, and commercial fisheries dealers. A total of 23 individuals were surveyed either in person or by phone during late summer/early fall. A recreational intercept survey was performed to estimate party and charter boats in Nantucket Sound over four months, and party and charter boat captains were contacted by phone. In addition, the MRFSS (Marine Recreational Fishing Statistical Survey) data were used to assess recreational fishing activity within Nantucket Sound (MMS 2008a).

A study by Stevenson et al. (2004) examined VTR data and clam logbook data from NMFS for fishing vessels in the Northeast Region to determine the spatial distribution of fishing activity by gear types by ten-minute square. This study was then compared with the vulnerability of Essential Fish Habitat of various commercial species to fishing by these gear types, to determine what areas of EFH in the Northeast are most likely to be adversely effected by fishing activity (Stevenson et al. 2004). Murawski et al. (2005), in order to evaluate changes to fishing activity in New England as a result of MPAs and seasonal closures, analyzed VTR and VMS data as well as fishery observer reports and port sampler interviews.

One study conducted within the Stellwagen Bank National Marine Sanctuary to compare the distribution of commercial fishing activity with the distribution of whales conducted monthly shipboard surveys along 5 kilometer tracks to analyze the distribution and density of fixed and mobile fishing activity (Wiley et al. 2003).

To characterize fishing activity in the region of the proposed Neptune LNG project, the EIS authors analyzed VMS data to evaluate the economic value of the area to fishing vessels originating in Gloucester, MA. This was done by looking at four years worth of VMS data to evaluate the area of activity, the ports of origin and catch landings, the duration of the trip, and the speed of the vessel to determine whether it was transiting or fishing. VTR data were also analyzed to determine the number of trips in the area. Additionally, sediment profile imaging was used to search for trawl scars to indicate evidence of fishing activity. Surveys were also conducted from vessels for lobster pots and gillnets (U.S. Coast Guard 2006).

To characterize fishing activity in the area of a proposed wind farm at North Hoyle in the UK, consultations and interviews were conducted with fishermen to determine areas of fishing activity, and individual meetings were held with skippers. These interviews and consultations were held during the baseline monitoring period, during the pre-construction period, and post-construction. Fishermen of various types (net fishermen, charter boat fishermen) were asked if they had noticed any differences in their catch or if they had needed to change their fishing practices since construction on the wind farm began (NWP Offshore Ltd. 2008).

Also within the UK, monitoring of fishery activity is done by aerial survey; the Royal Navy Fishery Protection Squadron and the DEFRA Sea Fisheries Inspectorate monitor activity within UK waters through quasi-random flights for enforcement purposes. The spatial data collected from these flights were used as baseline data to characterize the location and intensity of fishing activity for the EIA for the Lynn Offshore Wind Farm. These types of aerial data are not available within the United States. Commercial fishery landings data and information from questionnaires answered by the fishing industry were also used (AMEC 2002).

4. MARINE MAMMALS AND SEA TURTLES

This section of the review is focused on monitoring the changes that are expected to occur to fish and fishing activity as a result of offshore renewable energy construction, operation and decommissioning. When the project team considered the range of offshore renewable energy technology types and the existing research on potential impacts (see Task 1.2, Report on Monitoring the Potential Effects of Offshore Renewable Energy), it was determined that the greatest changes that are also most likely to occur to marine mammals and sea turtles are due to disturbance from noise during installation and operation. Noise impacts comprise the most significant concern; however, there are other types of impacts that also must be considered. Other potential effects identified within Task 1.2 include: changes to abundance and distribution caused by a change in habitat, reef effects caused by new habitat, and disturbance or attraction caused by EMF emitted from subsea cables. Blade strikes and pressure gradients are also a concern specific to tidal power devices. In most cases, the device type (i.e., wind, tidal, wave) does not influence the level of impact. The degree and nature of the impact is primarily controlled by the numbers and types of foundations placed on the seafloor. The degree of impact will also be different depending on the nature of the structure and construction method.

Effects can occur from the local level (e.g. around a single device) to the regional level, particularly if migration routes or entire populations are affected. The types of monitoring that will be appropriate for fish and fishing activity will vary greatly, and will depend on factors such as: the type of data required for monitoring; the size of the project and the spatial extent of the monitoring; management considerations such as stock and conservation status; the location of the fish species and the gear used to catch it in the water column; the spatial area that can be covered by static versus mobile gear; the potential for impact; and the marine industry using the monitoring protocols. The fish and shellfish species recognized as important to recreational and commercial fisheries will vary by region, watershed, and even community. The appropriate methods will vary depending on which are most appropriate to monitor the particular species of interest. Below are examples of various types of monitoring that can be used to monitor marine mammals and sea turtles.

The process for assessing potential impacts of offshore renewable energy development, other industrial activities, or other potentially harmful activities in waters under U.S. jurisdiction is well established in federal statutes. Unlike the other topic areas discussed in this document, some of the techniques for monitoring marine mammals are fairly well defined. The National Environmental Policy Act (NEPA) defines the overall environmental impact assessment process. For marine mammals, two other federal statutes come into play—the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). The MMPA applies to all marine mammals, including cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, sea lions, fur seals, and walrus), sirenians (manatees and dugong), sea and marine otters, and polar bear. The ESA only pertains to species formally classified as Endangered or Threatened under the Act, which can be entire species, subspecies, or smaller populations/stocks/subsets (distinct population segments [DPS] in the statute). At present there are 31 marine mammal species or DPSs listed under the

ESA, 24 as Endangered and 7 as Threatened. Although there is a large degree of overlap in the definitions, prohibitions, requirements, and regulations under the ESA and MMPA, there are some differences.

4.1. Types of Monitoring and the Potential Effects They Examine

There is a substantial range of potential impacts on marine mammals and sea turtles from the construction, operation, and decommissioning of ORED (see Appendix C, Renewable Energy Effect Matrix). Noise impacts comprise the most significant concern, however there are other types of impacts that must be considered (see farther below). Noise sources related to offshore renewable energy include: construction noise (pile-driving, possibly explosives), air-gun sounds if seismic survey is part of the site characterization work, operational noise (turbine sounds), ship noise, and de-commissioning (which might also involve explosives). In recent years the regulatory process has been strongly influenced by the Navy and its use of active sonar. Much of the regulatory machinery in the federal government has been occupied with dealing with the potential impacts of sound on marine mammals. In general, sea turtles are thought to have similar sensitivity to sound as that of seals, and as such, any monitoring/mitigation requirements that address noise effects in marine mammals (usually more stringent) will also cover sea turtles.

NRC (2005) included a conceptual model called PCAD (Population Consequences of Acoustic Disturbance) as a guide for a recommended future research program. The Office of Naval Research has more recently funded an extensive PCAD study (PCAD Working Group 2010) with the objective of expanding the NRC conceptual model into something much more quantitative. The PCAD project intends to develop elaborate Bayesian population models for selected marine mammal species with extensive long-term datasets, which would allow prediction of effects on their demography and life history from acoustic or other disturbance. The species under study include elephant seals, coastal bottlenose dolphins, and North Atlantic right whales (in that order). The first papers on the elephant seal model are currently in review (J. Clark, Duke Univ., pers. comm.).

While limited, several studies have been conducted on sea turtle hearing (e.g., Moein-Bartol and Musick 2003; O'Hara and Wilcox 1990; Ridgeway et al. 1969) and found that the hearing sensitivity in sea turtles is thought to be similar to that of seals, and therefore, sea turtles are covered by more stringent regulations pertaining to marine mammals.

Impacts Other Than Noise

There is a variety of other types of potential impacts on marine mammals and/or sea turtles that could result from offshore renewable energy development (see Appendix C, Renewable Energy Effect Matrix). Collisions with ships can be a serious source of injury and mortality for some species, most importantly the North Atlantic right whale (Kraus 1990; Waring et al. 2009).

Impacts other than noise and vessel collisions comprise a much lower level of concern for marine mammals and sea turtles. These include disturbance and habitat exclusion and/or destruction in the case of sea turtle nesting beaches and seal haulouts, chemical pollution, and electromagnetic fields. Entanglement in fishing gear (ropes and nets) is a serious source of mortality for many marine mammal and sea turtle stocks (NRC 1990; Waring et al. 2009; Allen and Angliss 2010; Caretta et al. 2010). Mooring cables used for floating devices (see Task 1.2

for more on the set up of various devices) could present an entanglement risk for marine mammals as well. Thin or slack mooring cables, or lines on devices for use by vessels to tie up alongside the device, would present the greatest entanglement threat (Boehlert et al. 2008).

4.1.1. Baseline Assessments

Because of the wide geographic scope of their operations and the risk of injuries to marine protected species from explosives and sonar, among other less important impacts, the Navy has been in the forefront of monitoring studies. The Chief of Naval Operations Environmental Readiness Division sponsored a workshop on marine mammal monitoring at Duke University in 2009 (DoN 2009a). The objectives of the workshop were to review existing monitoring efforts and methods, identify potential improvements to monitoring capabilities, and recommend research and development needed to meet future monitoring requirements. Methodologies, with advantages, limitations, and recommendations, include:

- Visual vessel-based surveys: Most species are readily observed from vessels, although the detectability varies among species. Zones where TTS and, especially, PTS are likely to occur are small enough that observers on the source vessel are likely to be best able to see animals inside those zones. Visual detections are distance-limited, and behavioral disturbance is likely to occur outside those ranges. Visual observations are also restricted at night and under low visibility conditions.
- Aerial surveys: Aerial surveys can cover larger areas in less time than vessel surveys, but are inherently dangerous. Some operations occur in offshore areas which are difficult to reach for aerial surveys. Aerial surveys properly conducted can serve for behavioral observations with minimal disturbance to the animals, which is difficult from ships. Focal behavioral follows and HD video recordings are currently being conducted during Navy aerial monitoring in the Southern California and Hawaii ranges by orbiting animals or groups at an altitude of 1500 feet and keeping about 1 km away horizontally, ensuring that the aircraft sound does not reach the target animals.
- Passive acoustic monitoring (PAM): PAM can provide continuous monitoring over significant areas, but with limitations. PAM provides good information on presence of individuals within approximate areas. Instrumented ranges like those in the Bahamas, southern California, and Hawaii allow for detection and tracking of individual animals, but would be impractically expensive to construct in other areas. Towed arrays concurrent with ship surveys have been used. Other PAM systems must be moored and retrieved to recover the data, and so would be of somewhat limited utility in monitoring/mitigation for specific events. Many PAM systems tend to be expensive, and generate immense datasets that must be processed, analyzed, and archived at additional costs. Automated classification algorithms to identify species are currently available for only a few species. Furthermore, inadequate information exists on the acoustic ecology of most species—what are the vocalization rates of individuals,

how do they vary by age/sex/behavior/reproductive status/season/time of day/etc.—that would allow estimating densities or abundances from PAM data.

- PhotoID: Repeated identification of individual animals has proven to be the best method for developing long-term information on reproduction, demography, life-history, and population trends, which is needed to address population-level impacts (e.g., Hamilton et al. 2007). But it requires long-term study effort, and is not equally applicable to every species.
- Tagging: Tagging provides more-or-less detailed information on location, movement, and habitat use patterns by individuals. Different types of tags provide different levels of resolution and different durations. Difficulties include attachment success and duration, tag life (battery technology), and numbers of tags necessary to detect population patterns and trends.
- Focused studies: These include controlled exposure experiments such as sound playbacks to tagged whales or to whales within instrumented ranges, or detailed behavioral observations of animals during naval exercises.

For most of these monitoring methodologies, the overlap between baseline assessments and post-construction or operational monitoring is substantial. Of the monitoring methods listed above, the method that is probably the least useful for baseline assessments is controlled exposure experiments. With respect to the baseline assessments, because marine mammal populations or stocks often occupy very large geographic ranges, studies are frequently extremely large programs. The Cetacean and Turtle Assessment Program (CETAP 1982), conducted by URI in 1978–1982, was the first extensive baseline assessment in the U.S. Atlantic. It included aerial and shipboard surveys of the continental shelf waters from North Carolina to Nova Scotia to assess the species diversity, distribution, abundance, and seasonality of whales, dolphins, porpoises, and sea turtles off the northeastern U.S.—related to the environmental assessment process for offshore petroleum exploration. The 1994 amendments to the MMPA mandated periodic assessments of all marine mammal stocks under U.S. jurisdiction (e.g., Waring et al. 2009; Allen and Angliss 2010; Caretta et al. 2010). Since that time, NMFS has been conducting aerial and shipboard surveys of the entire U.S. Exclusive Economic Zone in both the Atlantic and Pacific. Because of the ranges of some Pacific dolphin species, the NMFS ship surveys in the Pacific encompass an area from the west coast of the U.S. and Mexico to Hawaii. Because an area that large can only be surveyed with very sparse coverage, the NMFS Southwest Fisheries Science Center (La Jolla, CA) has been in the forefront of efforts to use habitat modeling to increase the extent, statistical precision, and spatial resolution of the resultant density and abundance estimates (Forney 2000; Ferguson et al. 2006a, 2006b; Redfern et al. 2006; Barlow et al. 2009; Becker et al. 2010). They have similarly been involved in expanding the use of PAM for marine mammal studies.

Of the study types mentioned above, shipboard and aerial surveys as well as tagging studies can all be used to monitor sea turtles in addition to marine mammals. Aerial surveys are much more effective at detecting sea turtles than shipboard surveys. Shoop and Kenney (1992) reported that 95% of sea turtle sightings came from aerial platforms, which was higher than for any other category: 56% of large whales, 68% of dolphins and porpoises, and 91% of large fishes (mainly sharks, rays, and ocean sunfish). The similar proportions for sea turtles and fishes suggest that the reason is likely that observers need a relatively high angle of view to see an animal that might be just below the surface. By the time a shipboard observer has that angle of view, the vessel is so close that the animal has detected the vessel and dived out of view. Neither aerial nor shipboard surveys are likely to be effective at detecting sea turtles smaller than some threshold size (Shoop and Kenney 1992; Kenney and Shoop in press). In an aerial survey experiment conducted in Florida in 1984 using plywood models over a range of sizes, Schroeder and Thompson (1987) showed that turtles smaller than 60-75 cm (carapace length) were difficult to detect from an airplane flying at 500 ft (150 m) and 100-120 knots (185-225 km/hr). Land-based or platform-based surveys, with or without divers, have also been used to monitor marine mammals and turtles in oil and gas construction and operations.

4.1.2. Post-construction Monitoring

Any of the methods listed in section 4.1.1 could be used to monitor marine mammals and sea turtles during the construction, operation, or decommissioning of offshore renewable energy installations (with the exception of PAM or Photo ID for sea turtles). Note that there is frequently no clear boundary between monitoring and mitigation activities, not least because monitoring is often required as mitigation as part of the Reasonable and Prudent Measures and implementing Terms and Conditions provided when an Incidental Harassment Authorization (IHA) or Letter of Authorization (LOA) is issued by the relevant federal agency. A larger question is the scale of impacts that any monitoring is intended to address. A simple BACI (before-after-control-impact) design may be quite adequate to detect short-term behavioral disturbance or shifts in distribution, given a population with a high enough density in the region of interest to produce reasonable sample sizes. Those short-term disturbances, however, may or may not have biologically relevant effects at the population level. Detecting population-level effects would require much larger spatial scales and much longer time periods.

As an evaluation of the marine mammal stock assessment process in the U.S. under the MMPA, Taylor et al. (2007) modeled the probability of detecting a “precipitous” decline in abundance, given recent levels of survey effort. A precipitous decline was defined as a 50% decrease in abundance over 15 years. The percentages of stocks where such a decline would *not* be detected were 72% for large whales, 90% for beaked whales, 78% for dolphins and porpoises, 5% for pinnipedscensused on land, 100% for pinnipedscensused on ice, and 55% percent for polar bears and sea otters. For species that are rare, sparse, or otherwise difficult to census, the statistical power to detect large changes is low even with frequent surveys.

Natural interannual variability can make it very difficult to detect anthropogenic changes in population distribution or other characteristics. Abundance estimates from the NMFS stock assessments are often significantly different between years, but with no evidence that the actual population size has changed (Waring et al. 2009; Allen and Angliss 2010; Caretta et al. 2010). The New England Aquarium has been conducting boat-based surveys and photoidentification studies of North Atlantic right whales during summer in the Bay of Fundy every year since 1980. Despite a population that is known to be growing, in 2010 they recorded the lowest number of sightings of any year in the entire period.

The spatial scale is equally difficult to deal with. Marine mammal and sea turtle populations can occupy immense geographic ranges. Known individuals from the western North Atlantic right whale population routinely range from Florida to Nova Scotia, but have been photographed in or offshore of Texas, the Florida Panhandle, the Gulf of St. Lawrence, Newfoundland, Labrador, Greenland, Iceland, the Azores, and a fjord in northern Norway. The larger a population's range is, the more difficult it becomes to differentiate a change in habitat usage in one location possibly caused by some anthropogenic disturbance from normal shifts in habitat use related to natural variability.

4.2. Current U.S. Monitoring Requirements and Standards

There are currently no standardized protocols for protected marine species monitoring and mitigation for potentially harmful activities in U.S. waters. Requirements tend to be ad hoc and dependent on a number of factors—activity, agencies involved, location, the specific statutory "hook" in play, and specific interests of the permitting agency.

4.2.1. Under Current Offshore Renewable Energy Permits

Cape Wind Energy Project, Massachusetts

There are at present no operational offshore wind farms in the United States, therefore it is necessary to rely on the European experience (see section 4.3). The Cape Wind EIS (MMS 2009) lays out a proposed monitoring and mitigation plan for marine mammals and sea turtles that provides some insight into what can be expected (section 9.3.5.6, pp. 9-23 to 9-30):

- For all phases, all vessels and aircraft must follow published NMFS and MMS guidelines on wildlife viewing and approaches; all operators must be trained on those guidelines and briefed on marine trash and debris.
- For pre-construction seismic surveys, a 500-m exclusion zone (EZ) around the seismic vessel for ESA-listed whales and turtles must be monitored by a NMFS-approved observer beginning 30 minutes prior to the start and continuing for 30 minutes after it is shut down; the seismic sound source must be ramped-up in intensity at the start to give whales and turtles a chance to hear it and leave the area; the EZ must be fully visible (daylight, no fog) and clear of whales and turtles for at least 30 minutes before ramp-up begins (although survey can proceed around the clock once begun); the sound source must be shut down immediately if a listed whale or turtle is sighted within the EZ.
- During construction, a 750-m EZ around pile-driving must be monitored by a NMFS-approved observer for 60 minutes prior to the start and 30 minutes after; pile-driving must begin with a soft start—3 strikes at 40% power followed by a 1-minute wait; if a whale or turtle is sighted in the EZ before starting, pile-driving cannot begin until the EZ has been clear at least 30 minutes, but it will not shut down for a sighting once started; the underwater sounds produced by the pile-driving must be measured at the beginning and periodically afterwards to verify and calibrate the EZ, which thereafter may be adjusted to a new distance based on a sound level

of 180 dB re 1 μPa, plus a buffer zone to be determined in consultation with NMFS.

- During operations, sound levels are expected to be so low that no impacts are predicted; therefore only the standard vessel and aircraft requirements will be in effect.
- For decommissioning, a complete decommissioning plan with associated monitoring and mitigation requirements must be submitted and approved.
- There are multiple reporting requirements for all phases, including reports of all sightings and all takes (observed mortalities, injuries, or behavioral disturbances) of marine mammals or sea turtles.

4.2.2. Other Offshore Marine Construction and Potentially Harmful Activities

Monitoring of Construction (Pile Driving)

Pile driving is likely to be the loudest noise source associated with construction of offshore alternative energy facilities (Madsen et al. 2006; Thomsen et al. 2006; Prior and McMath 2008)—far louder than the sounds produced during operations. The European experience has shown that pile driving has been the activity causing the greatest disturbance at wind farms (see 4.3).

Bailey et al. (2010) conducted field measurements from sounds of pile driving at two wind-turbine installations, in water deeper than 40 m, off the Moray Firth in eastern Scotland. There is a small local population of bottlenose dolphins in that region that has been well-studied and is of conservation concern. Received level was 205 dB re 1 μPa at 100 m from the source, and declined to undetectable above background at 80 km away. They concluded that bottlenose dolphins would have been injured only within 100 m of the pile driving, but could have experienced behavioral disturbance as far as 50 km away.

David (2006) reviewed the literature on noise levels produced by pile driving, hearing sensitivity of bottlenose dolphins, and the likely range of impacts. These include masking of whistles to 40 km away and echolocation clicks to 6 km, and temporary behavioral displacement. Recommendations for mitigating the impacts included seasonal restrictions, visual observers, a 500-m exclusion zone, soft starts, and bubble curtains. Prior and McMath (2008) recommended noise reduction at the source for mitigation, since a relatively small reduction provides a significant decrease in the range at which impacts might occur. They suggested that lattice-jacket bases provide a reduction in sound intensity from pile driving when compared with monopole bases, simply because they require smaller piles.

NMFS (2003) is the Federal Register announcement of issuing an IHA for harassment of California sea lions, harbor seals, and gray whales during construction of a replacement span for the San Francisco–Oakland Bay Bridge in California. The project anticipated driving 189 2.5-m piles and 70 1.8-m piles. There was a preliminary demonstration project to measure sound levels and test two noise-attenuation mechanisms—bubble curtains and a fabric barrier system. The peak source level estimated from the measurements (peak=207 dB re 1 μPa at 103 m) and acoustic modeling was 268.5 dB re 1 μPa at 1 m. The bubble curtain reduced measured sound pressures by at least 3 dB re 1 μPa and as much as 20 dB re 1 μPa for some tests. Mitigation and monitoring requirements in the IHA included: use of bubble curtains, a 500-m safety zone to exclude sea lions and seals beyond the 190 dB re 1 μPa range and gray whales beyond 180 dB re 1 μPa (which can be adjusted based on field measurements of the noise actually produced), soft starts (hammer strikes at 10-sec intervals for the first 3–5 min before speeding up to 1-sec intervals), 3 trained marine mammal observers (MMOs) at each site for at least 30 min before to 30 min after pile driving, baseline monitoring by boat and aerial surveys for 14 days prior to work beginning, noise monitoring, and reporting.

NMFS (2010b) is a similar IHA announcement related to replacement of the Manette Bridge in Bremerton, WA, involving both construction of the new bridge and demolition of the old one. Pile-driving was expected to be done using a vibratory rather than impact hammer, with the latter type used only if necessary to penetrate harder sediments. Demolition was to be done by conventional methods, but not explosives. The IHA permitted Level B harassment of 877 harbor seals, 516 California sea lions, and 2 gray whales, but predicted 0 takes of Steller sea lions and killer whales (both ESA-listed). Required mitigation and monitoring included: restricting activities outside of the periods when ESA-listed species are most likely to be present (no in-water activities 1 March–14 June), pile-driving only during daylight and when the entire safety zone is visible, establishing safety zones from empirical measurements of noise produced (190 dB re 1 μPa—Level A/pinnipeds, 180 dB re 1 μPa—Level A/cetaceans, 160 dB re 1 μPa—Level B/impulse, 120 dB re 1 μPa—Level B/non-impulse), at least 2 MMOs, delaying starts and shut-downs for any species seen within the Level A safety zone or ESA-listed species within the Level B safety zone, soft starts, and air bubble curtains if impact pile-driving is needed

Monitoring of Naval Activities

In 2009 and 2010, the Navy and NMFS completed the rule-making process for multiple training ranges and training range complexes in the North Atlantic and North Pacific (NMFS 2009d, 2009e, 2009f, 2009g, 2009h, 2009i, 2010f, 2010h). For each one, there is a 5-year Final Rule detailing the regulations for allowable takes of protected species and all associated monitoring and mitigation (with much overlap between monitoring and mitigation, since monitoring is required in part to mitigate potential impacts). There is also an overall Integrated Comprehensive Monitoring Plan (ICMP; DoN 2009b) that outlines the goals and objectives of monitoring, lists the questions that monitoring is expected to address, and summarizes methods. Completion of the ICMP was specified as a condition of the Final Rules and Letters of Authorization for each range complex. Navy Fleet Forces Command issued a 5-year IDIQ (“indefinite delivery, indefinite quantity”) contract in the spring of 2010 to a large collaborative team coordinated by a large consulting company to oversee monitoring in all of the training ranges. Then each range is issued 1-year Letters of Authorization that actually permit the activity and specify the allowable takes (e.g., NMFS 2009a, 2010g, 2010i, 2010j, 2010l, 2010m, 2010n).

The Atlantic Fleet Active Sonar Training (AFAST) LOA (NMFS 2009a, 2010n) specifies allowable takes of 32 different species or species complexes of marine mammals for a 1-year period. Almost all of the allowed takes are for Level B harassment (TTS or behavioral disturbance)—ranging from 36 Bryde’s whales up to 606,802 bottlenose dolphins (note that the number of bottlenose dolphin takes allowed is more than three times the total estimated abundance for all coastal and offshore bottlenose dolphin stocks off the Atlantic coast and in the

Gulf of Mexico [Waring et al. 2009], so the LOA permits multiple takes by disturbance of individual animals; this is true of permitted takes of a number of species). The only Level A takes permitted are 10 mortalities or injuries of beaked whales (all species combined) over the entire 5-year period. The LOA includes very specific mitigation procedures for each exercise type, including maintaining trained lookouts, reducing or ceasing sonar outputs if animals are observed (visually or acoustically) within specific distances, and immediate reporting of any dead or injured marine mammals. The monitoring plan laid out in the Final Rule (NMFS 2009i) is less specific, referring to the ICMP objectives and questions. It states that monitoring is to be carried out by a combination of methods, including vessel and aerial surveys conducted by independent research teams on separate platform (i.e., not Navy vessels and aircraft), passive acoustics, and MMOs aboard the Navy ships.

Monitoring of Seismic Exploration

NMFS (2010c) is a Federal Register notice of issuance of an IHA for a seismic survey in an area of 2370 km^2 in the Chukchi Sea about 240 km west of Barrow, Alaska, in water depths of 30-50 m. The survey was proposed by Statoil USA E&P to collect 3-D deep sub-bottom data for future oil and gas development. The plan was to conduct about 5,000 km of survey over a 60-day period using towed airgun arrays with an estimated source level of 245 dB re 1 μPa at 1 m. The estimated ranges at which the sound would attenuate to levels of 190, 180, 160, and 120 dB re 1 μPa were 700 m, 2500 m, 13 km, and 120 km, respectively. The current working values of threshold sound levels for behavioral harassment by impulsive and tonal sounds are 160 dB re 1 μPa and 120 dB re 1 μPa, respectively. The estimated numbers of exposures during the survey to received levels of 160 dB re 1 μPa or more included in the IHA were 184 belugas, 2 killer whales, 21 harbor porpoises, 158 bowhead whales, 144 gray whales, 2 humpback whales, 2 fin whales, 2 minke whales, 214 bearded seals, 6 ribbon seals, 6487 ringed seals, and 130 spotted seals. Required mitigation measures include measuring sound levels to confirm the modeling range estimates, safety zones inside the 190 dB re 1 μPa range for seals and 180 dB re 1 μPa range for cetaceans, shut-downs for sightings inside the safety zone, ramp-up of the airguns on starting, a 160-dB re 1 μPa safety zone for aggregations of 12 or more bowhead or gray whales engaged in feeding or socializing, ship speed reductions and avoidance of course changes within 300 yards of whales or in reduced visibility conditions, and additional measures to avoid interference with Alaska Native hunting. Monitoring requirements included (1) trained MMOs on the survey vessel and chase/monitoring vessels, comprising both experienced biologists and Alaska Natives; (2) acoustic monitoring to measure sound levels; (3) participation in a “shared science program” with other oil companies that includes a passive acoustic array installed to collect data on background ambient noise, seismic survey noise, and marine mammal vocalizations; and (4) reporting.

Monitoring of Offshore LNG Terminals

Two offshore terminals for delivery of liquefied natural gas (LNG) have been constructed and are in operation in Massachusetts Bay east of Boston. Northeast Gateway, operated by Excelerate Energy, was the first, followed by Neptune, operated by GDF Suez Energy North America. The two terminals are very similar. Each has two submerged turret-loading buoys (STLs) moored to the bottom and connected by flexible risers to subsea pipelines that eventually connect to the Hubline subsea gas pipeline. The STL couples to a fitting on the bottom of a specialized LNG tanker (referred to as an Energy Bridge Regasification Vessel [EBRV] by

Northeast Gateway and a shuttle and regasification vessel [SRV] by Neptune). On board the ship is a regasification plant that warms the LNG, converting it from liquid to gas and feeding into the pipeline and then directly into the regional distribution system.

NMFS (2010d) and NMFS (2010e) are Federal Register notices of issuance of 1-year IHAs for operation and maintenance of the Neptune and Northeast Gateway facilities, respectively. The primary sources of noise disturbance at each port are the thrusters used for dynamic positioning of the ship, with a source level of about 180 dB re 1 µPa at 1 m. The noise is never at the 190 dB re 1 µPa at 1 m level defined for Level A harassment for seals, and would be at the 180 dB re 1 µPa at 1 m Level A harassment threshold for cetaceans only immediately next to the ship. The estimated 120 dB re 1 µPazone of influence for Level B harassment varies with location and water depth, but is around 3 km. Both IHAs note that MMO logs during construction and operations of the ports recorded no obvious behavioral reactions by marine mammals. The IHAs are similar, however Neptune's is more complex because operators anticipated making major repairs to the port or pipeline in addition to routine operation and maintenance, causing added noise.

In the Northeast Gateway IHA, monitoring and mitigation are combined into the same sections. Required procedures include:

- MMO training for all bridge personnel and lookouts on the EBRV.
- Notification of the person in charge for all marine mammal sightings to enable avoidance.
- Compliance with the Mandatory Ship Reporting regulations.
- Slowing speed to ≤ 10 knots (18.5 km/hr) whenever there is a sighting or acoustic detection of a right whale.
- Maintaining ≤ 12 knots (22 km/hr) within the Traffic Separation Scheme (TSS), slowing to 3 knots (5.5 km/hr) within 3 km of the port and 1 knot (1.9 km/hr) within 500 m except as specified below for the various Seasonal Management Areas (SMAs) established to reduce ship collisions with right whales
- ≤ 10 knots (18.5 km/hr) in the Off Race Point SMA during 1 March–30 April.
- ≤ 10 knots (18.5 km/hr) in the Great South Channel SMA during 1 April–31 July.
- ≤ 10 knots (18.5 km/hr) in the Cape Cod Bay SMA during 1 January–15 May (although EBRVs are not expected to transit Cape Cod Bay).
- Maintaining, for the full operational lifetime of the port, the Research Passive Acoustic Monitoring system created when construction of the port began. The system consists of 19 Marine Acoustic Recording Units (MARUs) and 10 Auto-Detect Buoys (ABs), jointly operated by NMFS, the Stellwagen Bank National Marine Sanctuary (SBNMS), and Cornell University. The MARUs (often called "pop-ups") are submerged units that

record and archive underwater sounds; the unit is physically retrieved on command and the recordings (typically about 3 months of data) downloaded for analysis. The MARUs are deployed in the vicinity of the ports and in the nearby SBNMS. The ABs are deployed at 8-km intervals down the middle of the TSS. In addition to the subsurface recording and sound processing unit, they have a surface buoy with a telephone uplink that allows near-real-time reporting of right whale acoustic detections. The reports can be accessed by the ships or on-line (www.listenforwhales.org) (Fig. 4-3).

- Reporting.

In the Neptune IHA, mitigation and monitoring activities are specified in separate sections. Monitoring requirements are basically the same as for Northeast Gateway, including splitting the bill for the Research Passive Acoustic Monitoring system and detailed reporting. There is also a requirement to have two trained MMOs on board any vessel with dynamic-positioning thrusters. Mitigation measures are much more detailed, primarily involving major repair activities:

- Conduct major repairs during May–November (outside of right whale season) if possible.
- Monitor an 800-m safety zone at the repair site.
- Cease movement and stop any loud noise sources if a right whale is sighted within 500 yd (457 m) or any other mammal is sighted within 100 yd (91 m).
- All underway repair vessels stay at least 500 yd (457 m) away from right whales and 100 yd (91 m) away from all other marine mammals.
- Repair vessels ≥ 300 gross registered tons (grt) (272 kg) remain at speeds ≤ 10 knots (18.5 km/hr).

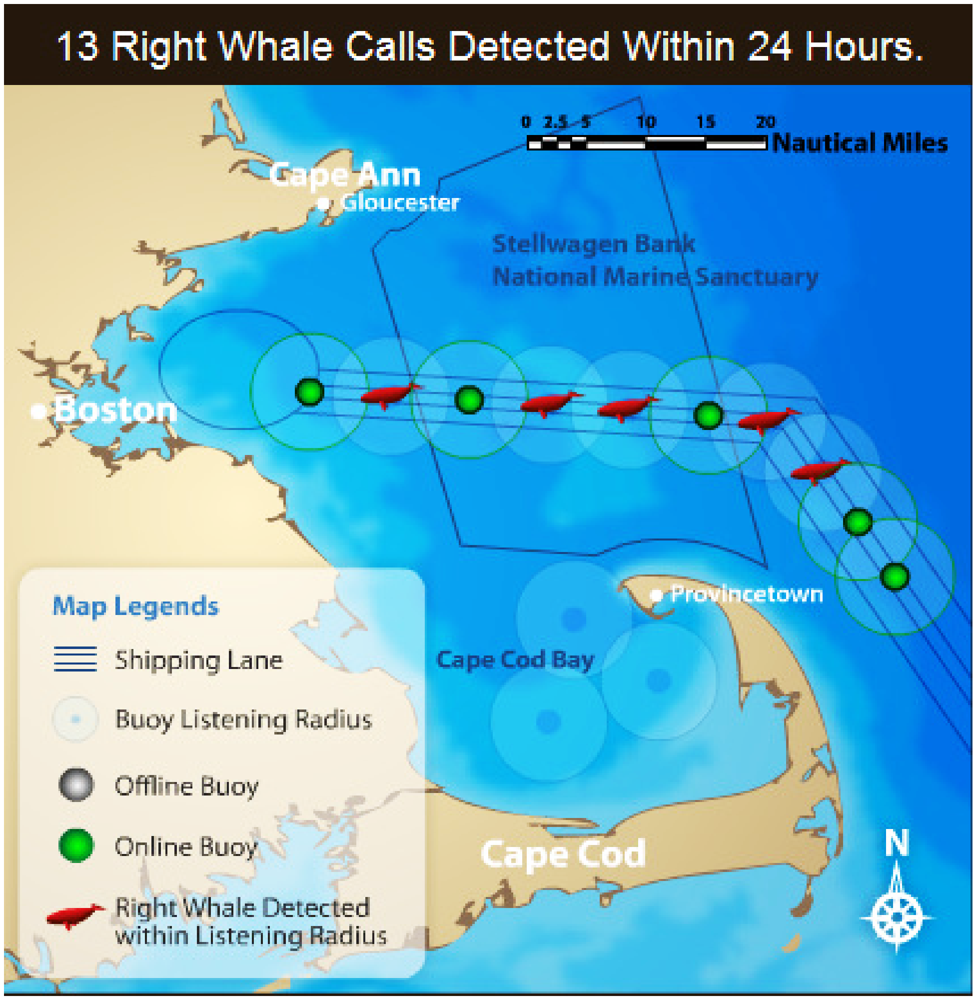


Figure 1. Near real-time right whale detections on the array of 10 auto-detect buoys in the Boston TSS (downloaded at 13:00 on 21 April 2011).

- Repair vessels < 300 grt (272 kg) reduce speed to ≤ 10 knots (18.5 km/hr) within 8 km of recent right whale sightings or detections.
- During December–April, shut down repairs if on-board MMOs at the work site if clear visibility is <800m.
- During December–April, any repair vessel leaving the dock for the work site must first contact the on-site MMOs; if a right whale has been seen within the previous 30 min they must hold at the dock for 30 min, then contact the MMOs again.
- Lookouts on transit barges and other support vessels must have MMO training
- Barges and support vessels maintain ≤ 10 knots (18.5 km/hr) in daylight, ≤ 5 knots (9.3 km/hr) at night, ≤ 5 knots (9.3 km/hr) within 5 km of the repair area, ≤ 4 knots (7.4 km/hr) if there is a sighting within 1000 m, and

idle speed for any sighting within 750 m or a baleen whale sighting within 1000 m.

- All repair vessels and SRVs maintain ≤ 10 knots (18.5 km/hr) in the Cape Cod Bay SMA during 1 January–15 May, in Off Race Point SMA year-round, and in the Great South Channel SMA during 1 April–31 July.
- All vessels should use the Boston TSS when approaching.
- Vessels should delay departure from the port if a whale is seen within 1 km or heard on one of the two closest ABs—until a sighted whale moves away or there are no acoustic detections for 30 min.
- Repairs or operations should be immediately suspended if "a dead or injured marine mammal is found in the vicinity of the project area, and the death or injury of the animal could be attributable to the LNG facility activities."
- Use of lights is restricted to the actual repair area, and they should be shielded so as

Monitoring of Explosives

Explosives are also sound sources—broad-band, high-intensity, and short duration (impulsive), with very fast rise times. Explosive impact monitoring is associated with naval training and exercises, decommissioning and removal of oil and natural gas production platforms (see Klima et al. 1988; Keevin and Hempen 1997; Florida Fish and Wildlife Conservation Commission 2006), some construction projects, and potentially decommissioning of offshore renewables facilities (see OSPAR Commission 2009 for a more detailed description). For monitoring and mitigation associated with naval activities (see above), explosives are considered together with active sonar.

4.3. CURRENT E.U. MONITORING REQUIREMENTS AND STANDARDS FOR OFFSHORE RENEWABLE ENERGY

Although there have been a number of reviews and recommendations (OSPAR Commission 2004, 2006, 2008; Gill 2005; David 2006; Madsen et al. 2006; Thomsen et al. 2006; Wilson 2007; Prior and McMath 2008; Rye et al. 2008; Inger et al. 2009; Boehlert and Gill 2010; JNCC, NE, & CCW 2010; Wilhelmsson et al. 2010), there seem to be few national or EU-wide standard requirements or protocols for monitoring of offshore wind-farms and other offshore renewable energy installations in Europe. The German Maritime and Hydrographic Agency has published a set of standards for assessing the environmental impacts of offshore wind farms on, among other resources, marine mammals (BSH 2007). The standards specify baseline surveys for two years prior to beginning construction, monitoring throughout the entire construction phase, and continuous monitoring during the operation phase for at least three years and as long as five years. Baseline and monitoring surveys are required both in the project area and in a reference area that is as environmentally comparable as possible to the project area. Sea turtles are not addressed; the range of studies required for marine mammals includes the following (note that the standards and associated specifications are quite clearly designed for harbor porpoises):

- Visual, line-transect aerial surveys during both the baseline and monitoring phases to assess the abundance, distribution, and habitat use patterns of marine mammals.
- Visual, line-transect shipboard surveys during both the baseline and monitoring phases with the same objectives, preferably with towed passive acoustic sensors, conducted jointly with bird surveys.
- Continuous passive acoustic monitoring of harbor porpoises with an array of fixed acoustic sensors to assess porpoise habitat use patterns and detect changes.
- Monitoring of ambient noise during the baseline phase, modeling to predict the noise propagation of anthropogenic noise during the construction and operation phases, and noise monitoring during the construction and operation phases to verify the model predictions.

Much of the available published information is for monitoring at the two major installations in Denmark—Horns Rev and Nysted. In those locations, the diversity of marine mammals is much lower than in many sites along the U.S. Atlantic coast. They primarily were interested in monitoring impacts on one cetacean (harbor porpoise) and two pinnipeds (harbor and gray seals). The primary methods employed included:

Passive acoustic monitoring (PAM):

Harbor porpoises use echolocation for foraging, navigation, and communication, and therefore can be monitored by listening for their clicks. At both Danish sites, studies used arrays of archival acoustic detectors designed specifically for porpoises (Carstensen et al. 2006; Teilmann et al. 2006a, 2008; Diederichs et al. 2008; Tougaard et al. 2009a; Clausen et al. 2010; Brandt et al. 2011) in a BACI (before, after, control, impact) design. During the first phase of the Horns Rev wind farm, two T-POD click detectors were set up inside the wind farm, and four reference T-PODs were set up to 25 km away from the wind farm. Monitoring continued for one year during the operational phase (Teilmann et al. 2006a). During the second phase, there were also six T-PODs used in monitoring - one in the middle of the farm, one just on the edge, and the others at distances of about 5, 10, 18, and 21 km (Brandt et al. 2011). Pre-construction monitoring began six weeks prior to construction.

At the Nysted wind farm, three T-PODs were set inside of the wind farm, and three were set at reference sites at a distance of 10 km. Baseline monitoring was conducted for a period of eight months, monitoring occurred during construction for a period of sixteen months, and continued for a period of two years post-construction (Carstensen et al. 2006; Teilmann et al. 2006a). A study at the Sprogø wind farm in Denmark deployed two T-PODs inside the wind farm, and two at about 20 km away for six months pre-construction, five months during construction, and eight months in the post-construction period (Tougaard and Carstensen 2011).

Passive Acoustic Monitoring was also employed at the Egmond aan Zee offshore wind farm in the Netherlands to detect harbor porpoises. The wind farm area and two reference sites were studied for one year using T-PODs prior to construction, and for one year during operation, two years after construction was completed. Two monitoring stations were established within the wind farm, while three were established at each of the reference sites, at a distance of 10 km from the wind farm (Scheidat et al. 2011). A similar study in Scotland used PAM for monitoring harbor porpoises and bottlenose dolphins during pile driving for two wind turbine installations (Thompson et al. 2010).

Visual surveys:

Visual aerial surveys were used to monitor numbers of seals hauled out at a few specific sites at Nysted. These were conducted on a monthly basis (Teilmann et al. 2006b; Edrén et al. 2010). Visual vessel surveys were used for porpoises and seals within and near the turbine array at Horns Rev. Thirty surveys lasting from one to three days each were conducted in total during the pre-construction, construction, and operation periods. These surveys were designed for harbor porpoises, and seal sightings were collected opportunistically (Teilmann et al. 2006a, 2006b). Boat surveys for porpoises were not conducted at Nysted because the densities were known to be too low for visual surveys to generate enough sightings and have enough statistical power to detect changes. Additionally, land-based visual surveys were used to monitor numbers of seals hauled out at a seal sanctuary near Nysted (Teilmann et al. 2006b; Edrén et al. 2010). Similar vessel surveys were conducted for porpoises, common dolphins, and minke whales in Scotland (Thompson et al. 2010).

Other surveys:

A camera was mounted on top of a tower overlooking the haul-out beach at the seal sanctuary near Nysted to monitor behavioral effects (Teilmann et al. 2006b; Edrén et al. 2010). Satellite-tracked radio tagging of harbor seals at both Horns Rev and Nysted and of gray seals at Nysted was conducted in the pre-construction, during construction, and operational periods (Tougaard et al. 2003; Teilmann et al. 2006b). Additionally, direct measurements of sounds generated from pile-driving in Scotland (Bailey et al. 2010), and at three different turbine models in Denmark and Sweden (Tougaard et al. 2009b), was conducted.

Study results:

Results of the various studies showed little effect of operation, in most cases, and some interesting differences between the two Danish sites. The most significant effects were seen from pile driving.

At Horns Rev, porpoise vocalization decreased significantly during pile driving compared to the baseline period before or the operational period after (Carstensen et al. 2006; Teilmann et al. 2006a, 2008; Tougaard et al. 2009a; Brandt et al. 2011). After a pile-driving event concluded, no clicking was detected for the first hour after pile-driving, and clicking was below baseline for 24-72 hours after at 2.6 km from the noise source. The negative effect was detectable out to an average distance of 17.8 km, and the duration decreased with distance. At 22 km, clicking increased temporarily, leading to the conclusion that the observed effect occurred because porpoises moved away from the pile-driving site. Within 4.7 km, the duration of the negative effect was longer than the average time between pile-driving events, therefore the porpoises were likely excluded from the wind farm site for the entire 5-month duration of pile driving (Brandt et al. 2011).

At Nysted, there was a similar, very substantial decrease in porpoise echolocation clicks detected during construction (Carstensen et al. 2006; Teilmann et al. 2006a, 2008; Tougaard et al. 2009a). The negative effect persisted for two years after construction was completed. Teilmann et al. (2008) speculated that the difference between the two sites with respect to how long the impacts lasted after construction was completed was related to the importance of the habitat to the porpoises (Horns Rev was presumed to be more important habitat based on the much higher densities prior to the start of construction). Harbor porpoises may tolerate a higher level of disturbance in a more valuable foraging habitat.

Little to no effect of routine operations could be detected at either site (Diederichs et al. 2008). Differences between locations within a wind farm were larger than the differences between inside the farm and at reference sites outside.

At both Horns Rev and Nysted, no effects on seals were observed during routine construction or operations, but the numbers of seals seen with the wind farm or hauled out at nearby sites was lower during pile-driving, indicating some short-term avoidance behavior (Teilmann et al. 2006b; Edrén et al. 2010).

The results of PAM studies at the Egmond aan Zee offshore wind farm in the Netherlands found that the number of harbor porpoises increased inside of the wind farm during the operational period when compared with the baseline period. This same increase was not seen at reference areas, indicating that the porpoises were attracted to the wind farm, either because of an increase in food due to a reef effect, or because they were avoiding disturbance within the wind farm (Scheidat et al. 2011).

In Scotland, acoustic results suggested some avoidance by porpoises, but the acoustic data for bottlenose dolphins and vessel sighting data for porpoises, common dolphins, and minke whales were too sparse for meaningful analysis (Thompson et al. 2010).

Satellite-tagged seals ranged more widely than expected, including the immediate areas of the wind farms (Tougaard et al. 2003; Teilmann et al. 2006b). However, the tagged harbor and gray seals spent less than 1% of their time within the wind farms. In addition, neither the spatial and temporal resolution of the data nor the accuracy of the satellite-generated location data was good enough to test for wind-farm impacts.

Modeled zones of influence derived from direct noise measurements indicated that pile-driving sound could injure bottlenose dolphins only within 100 m, but could cause behavioral disturbance as far away as 50 km, and would be detectable above background up to 80 km away (Bailey et al. 2010).For operational turbines, harbor porpoises were predicted to be able to detect the noise only within 20-70 m; for seals the range was <100 m to several km (Tougaard et al. 2009b).

5. AVIAN SPECIES

This section of the review is focused on monitoring the changes that are expected to occur to birds and bats as a result of offshore renewable energy construction, operation and decommissioning. Offshore renewable energy developments are not without potential environmental consequences on avian populations (Pelc and Fujita 2002, Jarvis 2005, Drewitt and Langston 2006, Fox et al. 2006, Grecian et al. 2010, Langton et al. 2011), thus the potential impacts on avian populations need to be considered when planning ORED. When the project team considered the range of offshore renewable energy technology types and the existing research on potential impacts (see Task 1.2, Report on Monitoring the Potential Effects of Offshore Renewable Energy), it was determined that the greatest changes that are also most likely to occur to birds are due to displacement or attraction effects due to construction or the presence of devices in the water, barrier effects (particularly from wind turbines), the their impacts on foraging, roosting, and migration, and collision mortality. Birds are most likely to be affected by wind turbines (and bats are only likely to be affected by wind turbines). Effects can occur from the local level (e.g. around a single device) to the regional level, particularly if migration routes or entire populations are affected.

At the present time, many of the documented effects and impacts on birds from ORED are based on studies of offshore wind facilities in Europe (Percival 2001, 2003; Drewitt and Langston 2006; Fox et al. 2006). There is higher uncertainty regarding the effects of wave and tidal ORED technologies on birds because only several pilot projects have been constructed and there have been few published environmental assessment studies (Leijon et al. 2003, Henfridsson et al. 2007, Grecian et al. 2010, Langton et al. 2011). However, some inferences can be made since it is likely that birds will show some similar effects to various aspects of these devices that they have exhibited with wind energy devices.

5.1. TYPES OF MONITORING AND THE POTENTIAL EFFECTS THEY ADDRESS

Ornithologists have developed a number of survey techniques to assess the potential impact of ORED on avian populations in offshore areas. The primary methods used to quantify changes in the spatial distribution and abundance of birds over a variety of spatial scales are ship-based and aerial surveys (Camphuysen et al. 2004). A robust BACI (Before- After Control- Impact) monitoring survey design is crucial to detect static avian effects such as displacement or attraction due to the physical structure of ORED devices. The ability to detect displacement or attraction (statistical power) is based on sample size for a given avian group or species, variability with those samples and the degree of the effect (displacement or attraction; see Inger et al. 2010).

Here the project team reviews documented and potential environmental effects from ORED on birds and investigate how these effects could potentially differ among technologies (i.e., wind, wave, tidal) and by scale of development (pilot, commercial, regional). Potential monitoring techniques and protocols to assess effects on avian populations are also suggested. The authors feel that several areas need to be monitored with the development of future ORED in U.S. waters and suggest future research for those effects that are poorly understood.

5.1.1. Monitoring the Spatial Distribution and Abundance of Birds

Understanding the spatial distribution and abundance of birds within a given area is essential for detecting any effects from ORED. The monitoring methods discussed below are used to collect baseline data on abundance and distribution, and can also be used to monitor changes to abundance and distribution during the construction and post-construction periods.

Ship-based surveys

Ship-based surveys could be used to gather data to model changes in the spatial distribution and densities of marine birds pre- and post- construction of an ORED. For pre-construction surveys, this information could be used to determine where key foraging and roost sites were located. Thus this information could be useful to decision-makers on where to locate OREDs to avoid potential effects and impacts on local avian populations. For surveys conducted pre-and construction, analyses based on ship-based surveys could then be used to assess the effects of an ORED on feeding displacement. An advantage of ship-based surveys is that be conducted over relatively fine-scales, so that changes in local distribution could be assessed.

Ship-based surveys had been the primary technique to monitor seabird distribution and abundance for decades. Systematic ship-based protocols were developed in the 1970s (Brown et al. 1975), and updated in the 1980s (Tasker et al. 1984, Briggs et al. 1985, Gould and Forsell. 1989) and 1990s (Komdeur et al. 1992) forming the basis of current systematic ship-based survey protocols used in avian monitoring studies today (Camphuysen et al. 2004). Tasker et al. (1984) developed a strip-transect methodology still commonly used today, which involves surveying birds only within a predetermined fixed strip (typically a 300m wide and long "moving box") in short time intervals from the ship's bow (port or starboard side). One primary assumption with a strip transect is that all birds present within the strip are detected, which is probably violated for many species (Buckland 2001). Observers typically record birds sitting on the water, and a "snapshot" method to count flying birds at set intervals. Komdeur et al. (1992) improved upon the strip-transect methodology by incorporating a distance sampling approach to Tasker's et al. (1984) methodology (referred to as a line-transect survey) by measuring observations into parallel narrow strips from the transect line to allow for corrections associated with reduced detection with increased distance from transect line (Buckland 2001). Knowledge of seabird distribution and abundance has benefited greatly from the development of these standardized protocols and this methodology is one of the standard avian monitoring techniques for predicting and assessing the effects of offshore development (Powers et al. 1983; Kalhert et al. 2000; Gill et al. 2002; Noer et al. 2000; Pollock et al. 2000; Blew et al. 2008; Geomarine 2010, Paton et al. 2010; Table 5.1).

As with any monitoring technique there are a number of strengths and weaknesses and biases associated with the ship-based monitoring technique (Camphuysen et al. 2004). One strength of ship-based surveys is that they allow for data collection at a fine level of detail (e.g. observations to species, identification of; endangered or threatened species, age, sex, individual behavior and flight direction/elevation of flying birds; Briggs et al. 1985) and simultaneous sampling of oceanographic variables (e.g., water temperature, salinity, chlorophyll a concentration). However, ship-based surveys can be moderately expensive, especially in offshore waters, where a large vessel (>20 m long) is required to have a stable viewing platform. Yet, costs are relatively low when compared to aerial surveys or remote techniques, especially in terms of the high level of detail they provide.

One negative aspect of ship-based surveys is that ship speed on surveys is relatively slow (5-15 kts/10-28 km/hr), thus covering a large geographic area requires considerable time and expense. Ship speed can also affect detection probabilities of different species of birds (Garthe and Hüppop 1999). This makes uniform coverage of a large study area within a small temporal window (e.g., one day) challenging. Another weakness is that ships will commonly displace birds (Borberg et al. 2005), which can lead to low biased estimates of density, or worse zero counts for those species particularly sensitive to ship disturbance (e.g., Red-throated Loons [*Gavia stellata*]). Ship cans also attract some species (e.g., gulls), therefore leading to biased density estimates. Camphuysen et al. (2004) recommended not recording birds entering the survey "box" if they entered from behind the ship or obviously followed the ship to reduce this bias. Individuals can also be counted multiple times if they are displaced by the ship and then recounted on subsequent transect lines. Ship-based surveys, like most visual survey techniques, do not work well in poor weather conditions and are not recommended or for that matter possible in rough sea states (Beaufort sea state > 5).

Incorporation of distance sampling into the ship-based survey protocol (Komdeur et al. 1992) was an important step to improve density estimates obtained using this monitoring technique. Many species show a significant decrease in detection probabilities greater than 100m from the transect line (Paton et al. 2010). It is important to note that in order to collect high quality data it is crucial to have observers trained in accurately estimating distance and also trained to concentrate much of their effort on detecting birds directly ahead of the boat on the transect line to ensure 100% detection of birds at a distance of zero (Buckland 2001, 2004). If observers are not well trained, fitted detection functions will be inaccurate (due to being fit on poor data) and thus lead to inaccurate estimates of avian density.

Aerial surveys

Aerial surveys have become an increasingly popular technique to monitor the distribution and abundance of seabirds over large areas due to recent improvements in navigation technology (e.g. GPS navigation). As with ship-based surveys, data gathered during aerial surveys pre-construction could be used to determine the locations of key foraging and roosting sites of marine birds. If data are gathered pre- and post-construction, they could be used to assess changes in the spatial distribution of marine birds that may represent the effects of displacement or attraction.

As with ship-based surveys, aerial surveys often take a line transect approach to incorporate detectability for improved estimates of density (Buckland 2001, 2004; Camphuysen et al. 2004). Aerial surveys, like ship-based surveys, are commonly used to predict and assess the effects of offshore development. The use of distance sampling and geo-referenced count data enables spatial modeling of bird density surfaces that also generate confidence intervals enabling statistical testing of before after types of design. These techniques can also build in environmental covariates to better model densities incorporating relevant features of the environment (such as depth, distance to coast) that affect bird distributions (Kalhert et al. 2000; Noer et al. 2000; Pollock et al. 2000; Christensen et al. 2003; Cranswick et al. 2003; Perkins et al. 2004; Petersen 2004; Bloor and Wratten 2006; Christensen et al. 2006; Paton et al. 2010).

One major advantage of aerial-based surveys is that recommended flight speeds on survey (100 kts/185 km/hr) and a wide survey window (1000 m) on both sides of the plane (with two observers) allow for coverage of a large geographic area in a relatively short period of time (Table 5.2). This attribute of aerial surveys has made them increasingly useful, with many studies showing high temporal variability (within a few days) in distribution and abundance of certain species making complete uniform coverage crucial within a short temporal window (Bloor and Wratten 2006, Paton et al. 2010). Fast flight speeds on survey also allow observers to record avian species particularly sensitive to disturbance (many individuals will not flush or dive until after the observers have recorded them). This allows for more accurate estimates of density for those sensitive species and can be critical data for an environmental assessment if those species are listed as threatened or endangered.

Line transect aerial surveys are expensive to implement and conduct due to required safety training for pilots and observers and a significant training period before observers are competent to survey. Komdeur et al. (1992) recommended at least 150-200 hours of flying time to become proficient with the line transect aerial survey technique, while Camphuysen et al. (2004) suggested a much more feasible 30 hours of training time.

Line-transect aerial surveys also do not always allow for identification of birds to species (Briggs et al. 1985), especially when there are multiple species in a survey area that are similar in appearance and behavior. It is also not possible to quantify flight altitude and flight direction of individuals and flocks with aerial surveys. This approach has severe limitations when recording flying birds since the angles used to bin distances from the transect line are based on the planes elevation to the water's surface and the fact that a relatively high proportion of flying birds are likely above the plane when on survey. In the U.S., it is possible to obtain a variance from the FAA to fly at low altitude (250 ft/ 76 m) for avian surveys to aid observers in seeing birds. However, the FAA still requires observers to fly higher over land (generally 1000 ft/ 305 m), which makes it difficult to survey nearshore waters (<1 km from shore) if transects are perpendicular to the coastline. Because transects should be oriented to go perpendicular to the density gradient of target species (Buckland 2001, 2004), in most situations aerial transects should be oriented perpendicular to the coast because densities of seabirds tend to be greatest nearshore and then change as one moves offshore (Buckland 2001, 2004; Camphuysen et al. 2004).

Most aerial surveys are conducted at a flight altitude of 250 feet (76 m), which is known to cause relatively high levels of avian disturbance among some species. The current consensus is that birds do not displace until after they are recorded, but this could lead to birds being double-counted on future transect lines if there are insufficient gaps between transects. Another issue with line transect aerial surveys it that they are limited to relatively calm sea states (< 3 Beaufort scale). Conditions this calm can be relatively infrequent in offshore waters and rough weather or consistent fog conditions, which can lead to infrequent survey effort during periods of peak abundance for particular species, especially if that peak takes place during a small temporal window. Glare is another factor, which can significantly reduce detection and is an environmental variable that is difficult to measure in more than a qualitative manner (low, moderate, high). It is important that observers are trained to go "off" survey during periods of high glare so density estimates are not biased low.

Table 1

Summary of sampling designs for studies that used ship-based surveys to monitor seabirds at offshore wind facilities or offshore areas.

Reference	Wind facility	Ship size (m)	Survey ship speed (kts)	Observer platform height (m)	Line-transect Sampling? Y/N	Survey by time interval or continuous?	Snapshot Surveys? Y/N	Number of Observers	Both sides of ship surveyed? Y/N	Spacing of transect lines (km)
Camphuysen et al. 2004		20-100	18.5 (9.3-28)	10 (5-25)	Y	Continuous	Y	2	Y	0.9-3.7
Blew et al. 2008	Horns Rev	46	NG*	3 m	Y	15 min, one per half hour	N	2	Y	NG
Kalhert et al. 2000	Nysted	22	12 -15	5 m	Y	2 min	N	2	N	2- 4
Noer et al. 2000	Horns Rev	NG	10- 11	7 m	Y	2 min	N	2	N	2- 5
Pollock 2000	None	NG	> 5	NG	NG	10 min interval	Y	NG	NG	NG
Powers 1983	None	NG	4- 12	NG	Y	10 min interval	N	NG	N	NG
Paton et al. 2010	None	27	10	5 m	Y	Continuous	N	2	N	Sawtooth

It is likely that a flight speed of 100 kts (185 km/hr) leads to significant underestimation of certain species that can dive below the surface for a long duration of time (some species may dive for several minutes). A stronger understanding of species-specific foraging dive duration and the recent ability to incorporate these dive rates into estimates of density will improve overall accuracy of these estimates.

It is important to note that just as with ship-based surveys, in order to collect high quality data it is crucial to have observers who are detecting 100% of birds at zero distance (Bin A with the aerial survey technique). If observers are not well trained, fitted detection functions will be inaccurate (due to being fit on poor data), leading to inaccurate estimates of avian density. Avian environmental assessments utilizing the aerial-based monitoring protocol are fairly consistent in their use of the technique although there are some inconsistencies that make direct comparisons between studies difficult (Table 2).

Radar surveys

Radar can be used a variety of ways to assess potential effects of ORED. Radar data collected pre-construction can be used to assess passage rates, migratory corridors, and flight altitudes at potential ORED sites, thus could be used to model collision risk. Data collected post-construction of an ORED could be used to assess the effects of avoidance (either during migration or daily commuting). Radar monitoring, coupled with visual ground truthing, is the preferred technique to determine barrier effects from an offshore energy device (Desholm and Kahlert 2005). Using radar can overcome the limitations of visual observations since the system can run surveillance both day and night with, typically, fewer limitations in poor weather (Desholm et al. 2004). Radar technology has been utilized for ornithological research for close to 75 years and its use has increased exponentially in the last 10 to 15 years as a result of alternative energy development in both terrestrial and offshore environments (Eastwood 1967, Kunz et al. 2007, Kelly et al. 2009). Radar is mainly used to assess avian flight ecology (number of targets, flight altitude, flight direction) near offshore and onshore wind facilities to predict and assess both collision risk and barrier effects associated with alternative energy development (Christensen et al. 2004; Desholm et al. 2004; Pettersson 2005; Huppop et al. 2006; Petersen et al. 2006; Kunz et al. 2004; Geomarine 2010; Mizrahi et al. 2010; Table 3).

Radar monitoring, coupled with visual ground truthing, is the preferred technique to determine barrier effects from an offshore energy device (Desholm and Kahlert 2005). Monitoring prior to construction and operation is not crucial to detect a barrier effect (flocks or individuals should clearly be flying around structures), but knowledge of movement corridors prior to construction allows for a clearer understanding on how birds were moving in the areas prior to and then after construction of a device.

Marine surveillance radar are typically used on ships, planes, and by meteorologists, and are either ‘T-bars’ or parabolic discs. Depending on the power output, they can track flocks of birds up to 240 km away. Only X-band and S-band radars have been used to date in ornithological radar studies. These surveillance radars are designed to detect targets in all directions (360°), but can be modified in vertical scanning modes to detect flight altitudes of birds 180° from the radar unit (e.g., Mizrahi et al. 2010).

Doppler radar is generally utilized to observe weather changes but the power of this tool can be used in avian identification. Using the S-band and a thin scanning beam from a parabolic disc, the system recognizes bird movements up to 200 km away. This type of radar detects the Doppler frequency shift in a target, which helps to distinguish the birds from their surroundings. Despite the differentiation, the system falters when seeking to identify individual birds amongst the collected radar data (Desholm et al. 2006). Nexrad radar is a Doppler radar, and it can track the velocity and direction of targets moving relative to the radar station, which is called the *radial velocity*.

Table 2

Summary of sampling design for studies that used aerial surveys to monitor seabirds at offshore wind facilities or offshore areas.

Reference	Windfarm	Flight altitude (m)	Flight speed (km/hr)	Line-transect Sampling? Y/N	Distance (m) birds were surveyed from plane	# of Observers	Spacing of transect lines (km)	Orientation of transect lines from land
Camphuysen et al. 2004		80 (76)	185	Y	44 - 1000	2	2	Perpendicular
Christensen et al. 2003	Horns Rev	76	185	Y	44 – 1000	2	2	NG*
Christensen et al. 2006	Horns Rev II	76	185	Y	44 – 1000	2	NG	Perpendicular
Cranswick et al. 2003	None	76	180	Y	60 – 1000	2	4	Perpendicular
Kalhert et al. 2000	Nysted	78	185	Y	44 – 1000	2	2	Perpendicular
Noer et al. 2000	Horns Rev	78	185	Y	NG	2	2	Horizontal
Petersen 2004	Horns Rev	76	185	Y	44 – 1000	2	2	Horizontal
Petersen et al. 2006	Nysted	76	185	Y	44 – 1000	2	NG	NG
Petersen et al. 2006	Horns Rev	76	185	Y	44 – 1000	2	NG	NG
Pollock et al. 2000	None	60	NG	Y	NG	NG	4 and 9 from land	NG
Paton et al. 2010	None - RI	152	160	N		2	3	Perpendicular
Winiarski et al. 2011	None - RI	76	160	Y		2	3	Perpendicular
Perkins et al. 2004	None - MA	152	90	N	56-212	2	2.3	Perpendicular
Geomarine 2010	None - NJ	76	110	Y	44-1000	2		Perpendicular

*NG = not given in paper

Military Tracking radars have been traditionally used by the military to track one radar target at a time. This high power output system utilizes a combination of an X-band and thin beam to analyze wing beats. The radar needs to lock onto a single bird for several wing beats to collect reliable data because the returned signal creates a three-dimensional image of the target. If this is not accomplished it can be difficult, if not impossible, to identify and analyze information about single bird(s) in a large flock. Additionally, results provide information about the birds' approach rather than the flight pattern in the immediate area of the wind farm. As such, this radar has not been widely used in wind farm studies (Desholm et al. 2006).

The value of radar data is that it is integral to baseline data collection because it is able to provide the volume of birds in a potential wind farm construction site while highlighting the effects of a wind farm during post-construction. Radar offers details about avian density, flight direction, height, pattern and speed, which are important information for wind farm construction. Once the data are collected, it could provide insight to potential areas of collision, displacement or barrier effects caused by the wind farm construction (Desholm et al. 2004).

Despite the benefits of radar surveillance, there are some negative aspects associated with this tool. Kelly et al. (2009) provides a detailed review of radar issues specific to working in an offshore environment. A few major issues are briefly reviewed below:

- <u>Fixed offshore platforms:</u> One major issue with using radar as a monitoring technique is that the unit needs to be installed on a stationary platform, which means either placing them on land or on a fixed platform at sea. This is particularly challenging when the radar needs to be placed offshore in deep water. Jack-up barges have limited utility because they are expensive to set up and maintain (estimates of $1,000,000 annually). If there is a meteorological mast associated with a potential wind facility that is one site where radar could be located.
- <u>Wave clutter:</u> Detecting and tracking birds on or just above the water's surface can be extremely challenging and often impossible because of the clutter on the radar caused by waves (Kelly et al. 2009).
- <u>Target categorization:</u> Target categorization, the ability to identify radar targets to a distinct biological group (bird, bat, insect, etc.) is another major issue associated with interpreting radar data (Zaugg et al. 2008; Kelly et al. 2009). Birds, especially small passerines have very similar radar intensities to insects and there is significant overlap in flight speeds (target speed) with the two groups which can be complicated by the effects of wind speed and direction. This makes it extremely difficult to use radar data to quantify numbers of birds (especially in areas of high insect abundance) and nearly impossible to make inferences at the avian group or species level. Many studies have accompanied radar observations with human visual surveying (often referred to as ground-truthing) to validate targets identified by the radar. This approach allows for species specific data from the radar data (flight elevation, direction, collision risk), but is limited to day light hours and fair weather conditions (Table 3).

- Recent technological advances are showing signs of successful discrimination of targets. Polarimetric weather radar has shown the capability to discriminate between birds and bats (Zrnic and Ryzhkov 1998; Bachmann and Zrnic 2007; Zaugg et al. 2008). Zaugg et al. (2008) developed a classification algorithm to automate recognition of bird targets that has been successfully tested in different locations and times of day.

- Proprietary software: Lack of an automated tool to analyze avian radar data limits comparisons between radar studies where different proprietary software is used to analyze the data, making comparisons between studies difficult and inconclusive (Table 3). Taylor et al. (2010) recently developed an open source platform, called radR. to allow comparisons in the future and more rapid improvement in radar analysis software. The combination of relatively inexpensive marine surveillance radar and free open source software could result in another rapid increase in ornithological radar research and the development of more extensive avian radar networks.

- Weather: Radar works well in most weather conditions except heavy precipitation (rain, snow and fog). X-band radar, due to its relatively small wavelength (3 cm), is easily saturated by precipitation. S-band radar is also affected by precipitation, but newly developed algorithms (Constant false Alarm Rate) allow for detection of biological targets (Kelly et al. 2009). The only radar system that is unaffected by poor weather is the Pulsed Doppler radar (Desholm et al. 2004).

Due to the lack of standardized radar monitoring approach and inconsistencies with how data are analyzed and interpreted with the use of proprietary software, comparisons between radar studies using different technologies are often extremely difficult (Table 3).

Table 3

Summary of sampling design for studies that used radar to monitor bird flight ecology at offshore wind facilities or offshore areas.

Reference	Windfarm	Land-based? Y/N	Sea-based? Y/N	Radar model spec.	Vertical ? Y/N	Horizontal? Y/N	Distance surveyed (m)	Ground-truthed? Y/N	Analysis by proprietary software? Y/N
Blew et al. 2008	Horns Rev	N	Y	Decca BridgeMaster E & Raytheon Pathfinder	Y	Y	500-1500 m	Y	Y)
Blew et al. 2008	Nysted	N	Y	Decca BridgeMaster E & Raytheon Pathfinder	Y	Y	500-1500 m	Y	Y
Christensen et al. 2004	Horns Rev	N	Y	Furuno FR2125 or FR2110	NG	NG*	11 km	Y	N
Desholm 2003	Nysted	N	Y	Furuno FR2125	Y	NG	12 km	N	N
Desholm et al. 2005	Nysted	N	Y	Furuno FR2125	Y	NG	11 km	N	N
Kalher et al. 2000	Nysted	Y	N	Furuno FR2125	Y	Y	500m (vertical) - 3km (horizontal)	Y	N
Mizrahi et al. 2010	None	Y	N	Furuno FAR2127BB	Y	Y	<3 nm	Y	Y
Petersen et al. 2006	Nysted	N	Y	Furuno FR2125	Y	Y	NG	Y	N
Petersen et al. 2006	Horns Rev	N	Y	Furuno FR2125/ FR2110	Y	Y	11 km	Y	N
Pettersson 2005	Utgrunden/Yttre Stengrund	N	Y	NG	NG	NG	7 km south of observation line		N

* NG = not given in paper.

Acoustic surveys

Acoustic surveys that monitor flight calls of migratory birds allow ornithologists the opportunity to potentially assess movement rates of specific species of nocturnal migrants, particularly passerines and possibly shorebirds. Many monitoring schemes want to assess movements and collision risk for specific species of birds (e.g., endangered species or species of special concern) that are nocturnal migrations (Burger et al. 2011). Obviously visual surveys could be used to assess movement ecology of birds during the daylight hours. However, many species of birds are nocturnal migrants, thus developing techniques that can be used at night are important. Acoustic monitoring has the potential to meet this objective as one can monitor bird flight calls for species recognition (Evans 1998, Larkin et al. 2002, Farnsworth 2005; Burger et al. 2011). Evans (1998) documented the flight calls of about 200 species, of which at least 150 species were sufficiently distinctive to identify with certainty. Nocturnal call counts of migrating birds can be useful as indices of nocturnal bird densities (Larkin et al. 2002, Farnsworth et al. 2004). Automated monitoring of night-flight calls could provide information on migration routes, timing, and relative migration density for many species of birds. Such information has application for conservation planning and management, as well as for assessing population trends (Evans and Rosenberg 2000).

To our knowledge there is currently no standardized approach for acoustic surveys. However, because there is extensive variation in calling rates within and among species, it will be difficult, if not impossible, to measure the density of birds aloft from flight calls alone (Farnsworth 2005).

Call counts are not constant based a thorough literature reviews conducted by Farnsworth (2005). Calls increase with cloud cover and lower cloud ceiling, particularly under artificial lighting (see Farnsworth 2005). Call counts increase as birds approach boundaries between air masses of different density, such as precipitation, high winds, or poor visibility, which can force birds to descend or congregate. Call counts can increase with passage of cold fronts during fall migration and decreasing temperatures. It is not known whether calling mainly occurs when birds are close to the ground, but there is some indication topographic features, such as mountains and coastlines appear to concentrate flight calls. There appears to be temporal variation, with 90% of thrush vocalization recorded in the hours before dawn. For example, Farnsworth and Russell (2005) reported the peak of call counts occurred in the two hours before dawn. One final interesting note is that the birds in North America exhibit different calling patterns than birds in Europe – New World species tend to call more frequently, at greater magnitude, and more species elicit calls (Farnsworth 2005), thus acoustic monitoring might be more effective in North America than Europe if detection probabilities are in fact higher.

There is limited experience using acoustic monitoring in offshore environments. Dierschke (1989), as reported in Desholm et al (2006), reported that very few species were calling intensively over the North Sea, and hence, that the acoustic monitoring was highly biased towards a few species for offshore monitoring programs. This concurs with Blew et al. (2008), who used experienced human observers to conducted manual calling counts at Horns Rev and Nysted wind facilities in Denmark. They recorded every bird call during 10 min every half hour from twilight in the evening to twilight in the morning, with at least 5 min separating calling periods. Observations were conducted on 163 nights (1468 hours). At Horns Rev during fall migration, thrushes (64% of birds; mainly redwing and songthrush and blackbird) and robin

(32% of detections) dominated, with a similar species composition at Nysted (thrushes 44%, robins 48%, with substantial numbers of dunnock (3%) and finches (2%). As has been found with radar studies, only one night in the 2005 had high detection rates and 3 nights in 2006. Blew et al. (2008) did determine that bird call counts were several times higher in autumn than in spring, with call counts higher at Horns Rev than at Nysted. This was a labor-intensive study that provided limited information on passage rates of all species moving through their study area.

Thus there is a need to develop automated systems that monitor flight calls. There have been a number of attempts to develop automated acoustic systems to monitor avian migration (e.g., Kwan et al. 2006), with most efforts focused on land-based systems (Evan 1998, Larkin et al. 2002). Evans (1998) pointed out an advantage of acoustic monitoring is that there is no lower height limit of bird detections, thus birds flying through the rotor zone could be detected. In contrast, radar systems do have a lower height limit, thus radar studies could miss birds flying at lower altitudes. Acoustic monitoring does have upper altitude limits, but these are well above the upper boundaries of the largest 5 MW wind turbines, thus acoustic monitoring could be a useful technique for risk assessment of wind facilities.

Farnsworth and Russell (2007) used a microphone system to record avian flight calls from an oil platform in the Gulf of Mexico on 30 nights from 9 September to 2 November 1999. They recorded 2762 calls, with 2329 calls identified to species. Nine species represented 23% of identified calls, with one night (1017 of 2762 calls) accounting for most of the detections. Movements were restricted to a few nights, with 98% of calls on 13 nights and 40% on one night. Recordings were difficult due to mechanical, wind and wave noise issues.

Verhoef et al. (2004) attempted to develop a bird-turbine collision system based on a microphone linked to a video camera. The system was designed to detect the sound of birds hitting the turbine structures. However, this system had major problems, such as the background noise of larger turbines exceeded original expectations, thus the signal from avian collisions could not be separated from background mechanical sounds. The camera images were poor, thus they were unable to use nocturnal images for species recognition (Verhoef et al. 2004).

The best effort to monitor avian migration in an offshore environment was by Hüppop et al. (2006) in Germany. They detected and recorded calls automatically with a directional microphone (Sennheiser ME67) and the specially developed software AROMA. On their offshore platform (FINO 1), they verified 70 different species by the automatic flight call recording. Over 70% of the registered flight calls (n = 19 776 individual birds) were from thrushes and around 10% came from waders and some other species of passerines. Interesting, they detected a strong correlation between flight calls and thermal imaging records, but a weak relationship with vertical radar detections. The largest numbers of detections near their platform came on drizzly or misty nights. Most detections (76%) by the automated call recording system were at night. Research by Hüppop et al. (2006) showed that under poor visibility conditions, large numbers of passerines were attracted to illuminated offshore platforms and some species collided in large numbers.

High definition videography surveys

Recently, biologists have been trying to develop automated systems to record seabirds during aerial transects with high definition videography (Maclean et al. 2009, Thaxter and Burton 2009;

Table 4). Survey data can be managed and reviewed by a ground-based system. Traditional aerial surveys require trained observers to collect data but this technology reduces the necessity of observers (Hexter 2009). However, someone must be present to control the camera during the surveys because current technology is not sophisticated enough to focus or orient itself automatically (Maclean et al. 2009).

The technique features either single or multiple cameras stabilized in the plane using a gyroscopic camera mount (Hexter 2009; Maclean et al. 2009; Mellor et al. 2007, 2008; Table 5.4). Flight altitudes range from 76 m to 1 km with speeds from 153 to 270 km/ hr during aerial high definition video surveys (Burt et al. 2009; Hexter 2009;Maclean et al. 2009; Mellor et al. 2007, 2008; Thaxter and Burton 2009; Table 25). At this time, flight speeds are limited by camera technology but as camera capabilities increase, so will the potential for aerial surveys. A variety of aircraft have been used to conduct videography surveys (helicopter, Diamond DA-42 MPP, Partenavia P 68). While helicopters have greater maneuverability potential than planes, the navigation system in a plane allows the aircraft to follow transect lines better than a helicopter, thus decreasing the cost of the survey.

Early aerial surveys collected data in relatively narrow strip (30- 40 m) transects. Future studies anticipate surveying a 200 m transect strip (Maclean et al. 2009). As the image quality improves, these surveys will become less expensive since flights will be able cover more space in less time with a highly detailed result (Maclean et al. 2009). Presently, 1080x1920 pixels (2.1 mega-pixels) are the common video resolution for these high definition video surveys (Hexter 2009; Maclean et al. 2009; Mellor et al. 2007, 2008; Thaxter and Burton 2009).

High definition cameras deployed in aerial surveys provide quality images. Earlier aerial surveys have not possessed this technology and thus relied on observer-based surveys with limited visual representation of their observations. This method is desirable due to the combination of image quality and expanded survey coverage.

Benefits to this type of monitoring technique include the opportunity to fly at higher elevations, which will minimize disturbance to birds. As aircrafts become more sophisticated, their maneuverability increases. The ever-growing technology has been and will continue to be an advantage to this monitoring method. Using high definition video equipment allows surveillance planes to revisit a transect strip where birds had previously been recorded easier than a ship-based survey. This feature enables subsequent studies to be conducted in the same area (Thaxter and Burton 2009).

Studies that consist solely of visual surveys may now be supplemented with high definition video technology. The equipment records all species in the immediate area (e.g., marine mammals, sea turtles), not just birds seen during visual observations. Using high definition video technology can lead to identifications that include a permanent record of the observations, thus allows verification of identification that are not feasible with visual observations. Video surveys also decrease the error of traditional visual surveys since the video can be reviewed and counting errors are reduced during post processing. Aerial surveys that use high definition camera technologies can fly at greater altitudes than other surveys. Another benefit associated with higher altitude flights is a plane's ability to overlap the coast. Coastal areas are easier to survey at higher elevations and FAA regulations do not permit low elevation flights over the coast: pilots typically have to fly at >1,000 feet (305 m) altitude over coastal landmasses. Lower flying planes maintain a greater distance from the coast making visual surveys more difficult in order to avoid interference with developed coastline. Utilizing superior video technology makes coastal data collection possible (Maclean et al. 2009). Finally, another benefit is safety. Planes conducting low elevation visual surveys should have two pilots and typically two observers.

A disadvantage associated with using videography includes inconsistency among studies. Since there is not a standardized system to complete these surveys, assessments are more difficult to complete. Implementing guidelines (aircraft, altitude, flight speed, camera type and angle) to combat these irregularities will create compatibility in high definition surveys. Despite the growth of the technology, there are still issues with the system. Since camera angles and light may limit the video equipment's ability to capture every target, surveys may need to be supplemented by trained observers (Thaxter and Burton 2009).

This technique could benefit from the camera focus having a locking mechanism to reduce operator responsibilities, to accommodate for low light, and attempt to keep the mage width at 40m for a 2000 pixel image (Mellor et al. 2008).

Biologists may never have a standardized high definition platform. Camera technology has improved dramatically over recent years, which has increased the capabilities aerial surveys. In future studies, using a multiple high definition cameras during surveys is highly recommended. This technology will allow surveys to continue without disturbing area birds (Mellor et al. 2008).

Table 4

Summary of sampling design for studies that used HD videography to monitor the distribution and abundance of birds at offshore wind facilities.

Reference	Wind Facility	Aircraft	Twin engine? Y/N	Flight altitude (m)	Flight speed (km/hr)	Number of cameras	Camera specs.	Video resolution
Burt et al. 2009	None	NG*	NG	76	200	4	NG	NG
Hexter 2009	Crown Estates (future)	Diamond DA-42 MPP	Y	609	185	1	Sony F950 mounted in a Cineflex gyroscopically stabilized mount.	1080x1920 pixels (2.1 mega-pixels)
Maclean et al. 2009	None	Partenavia P 68	Y	76	200	1	gyroscopically stabilized mount	1080x1920 pixels (2.1 mega-pixels)
Mellor 2008	NG	Diamond DA-42 MPP	Y	210 -600	185	1	Cineflex gyroscopically stabilized HD media system	1080x1920 pixels (2.1 mega-pixels)
Mellor et al. 2007	NG	Helicopter	NG	400 m - 1 km	153	1	gyroscopically stabilized mount	1080x1920 pixels (2.1 mega-pixels)
Thaxter et al. 2009	Crown Estates (future)	NG	NG	609 m	270	4	NG	1080x1920 pixels (2.1 mega-pixels)

* NG = not given in paper.

Mellor et al. (2008) concluded that a comparison of two avian studies, one with and one without high definition equipment, showed no evidence to suggest any limitations of the high definition camera technology. Before any widespread monitoring system can be executed, further studies need to be conducted on cost comparison and advantages over traditional visual aerial surveys (Mellor et al. 2008).

As the equipment advances, so do resolution and survey success. Additionally, the creation of a software system that identifies recorded species may reduce review time and increase analysis speed. However, testing of these systems is necessary prior to widespread usage. High definition video technology still has some features that need to be adjusted but the authors suggest that it will become the standard for video data collection once the technology is improved.

Satellite and Radio-Tracking technology

Individual avian tracking is a relatively new field, which has taken advantage of rapid advances in communication technology, such as cell phone technology. Technologies include: VHF radio telemetry, satellite telemetry (platform terminal transmitters), geolocators, and time-depth and altitude recorders (Louzao et al. 2009, Perrow et al. 2006, Griffin et al. 2010). These transmitters can give individual information on a large geographic scale (satellite telemetry - location of breeding and wintering grounds) or at a more local scale (altitude recorder – flight height profile on wintering grounds). In respect to alternative wind energy development, these technologies have mainly been used to assess whether certain species inhabit certain geographic regions where they are hard to monitor (Perrow et al. 2006, Louzao et al. 2009; Burger et al. 2011), but have also been used on a smaller scale to investigate movement ecology of species that are typically have a higher predicted collision risk and inhabit areas where wind facilities are planned on being installed or are in operation (Griffin et al. 2010).

There are currently no standardized approaches in respect to implementation of individual tracking technology. Many of the applications of this type of technology are site specific and research objectives and species studied heavily influence the type of technology being used and how often data is recorded on those devices.

Current limitations associated with these individual tracking technologies are the high costs for the units themselves and charges associated with downloading data, which has a direct impact on study sample size and thus the ability to make inferences that are statistically significant. Louzao et al. (2009) used ship-based surveys plus tracking data to assess movement ecology of Cory's shearwaters (*Calonectris diomedea*) at a variety of spatial scales, which is the direction that studies may undertake in the future. In addition, future advances in technology and increases in demand should lead to reduced costs and larger sample sizes. Unfortunately due to the sometimes negative effects on individuals carrying these types of devices, they are not allowed on most rare or threatened species where data on movement and flight ecology are needed the most in respect to proposed development.

5.1.2. Dynamic Effects

Monitoring collision mortality

The potential impacts of the physical structure of an ORED above the water surface are likely greatest for wind and some wave-powered alternative energy technologies because these technologies can have significant structures above the water surface. For example, 5-MW wind turbines currently being designed for European offshore waters would be over 150 tall, with a rotor diameter of 128 m, a hub height of 90 m, and a 13,000 m^2 sweep area (Jonkman et al. 2009). Large static structures in the offshore environment are known to be a hazard to birds, for example offshore oil and gas platforms can under certain conditions become a collision risk for birds (Tasker et al. 1986; Wiese et al. 2001). At the same time, onshore wind facilities are estimated to kill 2.3 birds per wind turbine per year in the U.S. (NWCC 2004) and up to 50 per year in Europe (Hötker et al. 2006). Thus, these large offshore facilities have the potential to be a major collision risk under certain environmental conditions.

In contrast, marine hydrokinetic (MHK) power generation devices mounted on the seafloor, have a relatively small profile above the water surface, thus the potential impacts on most species of birds are probably less (Pelc and Fujita 2002, Grecian et al. 2010; but see Langton et al. 2011). The potential for collisions or other physical effects below the water surface are likely greatest for tidal and some wind-based ORED technologies because they have will have the largest structures below the water surface (Boehlert and Gill 2010; Langton et al. 2011).

Collision monitoring has mainly focused on birds colliding with rotating turbine blades on offshore wind devices where risks are believed to be significantly higher than with collision with the static structures themselves (e.g., wind tower). There have been two research efforts that have used various types of thermal infrared cameras to assess avian collision risk at wind turbines (Desholm et al. 2006). Recently in North America, bat biologists have used infrared systems to assess collision rates at land-based wind farms (Horn et al. 2008). The use of thermal imaging cameras was developed in an attempt to have an automated, remotely controlled, cost-effective system that could be operated 24 hours per day to detect specific collision rates at a wind turbine. The theory is that thermal infrared cameras can detect animal movements under all light conditions, including total darkness, thus have the advantage over video cameras that they can be used at night to potentially detect nocturnal collisions (Desholm 2005, 2006).

The earliest versions of infrared cameras needed an external infrared source to illuminate the object interest (e.g., body heat of an animal). The first effort to use this technology was in Holland where Winkelman (1992) used a thermal imaging camera to detect avian collisions at a land-based wind facility. Winkelman (1992) in the 1980s used one thermal camera that could detect a duck at a distance of 50–250 m, 600 m, and 3 km for 15°, 5° and 3°, respectively. In this Dutch study, 15 of 65 birds that came near the rotor sweep zone collided with the turbine blades. However, not all collisions resulted in death, and 4 birds continued their flights. Apparently birds were swept down by the wake in 6 of 14 nocturnal incidents and not by the blades (see also Kunz et al. 2007).

Table 5

Summary of sampling design for studies that used infrared technology to monitor avian collisions at offshore wind facilities.

Reference	Country where study conducted	Wind facility	Turbine mounted? Y/N	Model spec.
Desholm 2005	Denmark	Nysted	Y	Thermovision IRMV 320V with 24-degree lens.
Desholm 2003	Denmark	NA	Y	Thermovision IRMV 320V with 24-degree lens.
Desholm et al. 2004	UK	NA	Y	Thermovision IRMV 320V with 24-degree lens.
Petersen et al. 2006	Denmark	Nysted	Y	Thermovision IRMV 320V with 24-degree lens.

At the Nysted wind facility in Denmark, a Thermal Animal Detection System (TADS) was developed and used in conjunction with surveillance radar to assess collision rates (Kahlert et al. 2000, 2004; Desholm 2003, 2005, Desholm et al. 2006). The TADS were capable of assessing animal movements in 30% of the area swept by the 42 m long turbine blades. The TADS was able to detected individual waterbirds and passerines at distances of up to 150 m and 30 m, respectively. Specific software in this system initiated the downloading of video sequences onto the hard disk when at least one pixel in the field of view exceeds an operator defined threshold temperature. Therefore, primarily birds passing the field of view were recorded, with few empty video sequences (Desholm et al. 2006).

At Nysted, only one TADS system was placed on one wind turbine and operated for one spring (Desholm 2005a) and one autumn (Desholm 2005b). A total of 1944 images were captured, there was only one incident when a bird (a passerine) came close to rotor blades. In five other events, 4 passerines and one waterfowl flock came near the near the turbine, but not close enough to be affected by the rotor blade (Desholm 2005). Based on this one TADS in combination with a detailed radar study, Desholm (2005) hypothesized that 68 (95% CI = 3 to 484 individuals) Common Eiders could collide with turbines at the 72 turbine facility each fall.

Desholm et al. (2006) reported some limitations of infrared cameras. First, the limited field of view is a drawback in terms of assessment, particularly when the cost of the appliance is taken into account. Second, there are probably few days when conditions are right for high collision probabilities. For example, nights with a large numbers of birds passing through an area and when there is a sudden change in visibility conditions (e.g., fog) could lead to high mortality rates at a wind facility, which has been documented on land-based superstructures and offshore platforms (see Desholm et al. 2006). Thus having a system in place to document these types of events will be a challenge.

Recent work suggests there are more cost effective means to monitor collision rates at turbines. Pandey et al. (2007) developed an acoustic emission sensors (microphones) thought to be the most viable sensor, with accelerometers ranked second. They also evaluated fiber-optic sensors and felt they were not suitable to assess collision rates due to their costs.

Bats

The potential impacts of OREDs on bat populations are just beginning to be understood. Based on the physical structure of most ORED technologies (i.e., wave or tidal generation facilities), those technologies that have a profile just on the surface (e.g., wave generated technologies) or subsurface (tidal generation facilities) will have no impact on bat populations because over water bats are only in flight, thus there is little potential for bat populations to be impacted.

However, there is the potential for offshore wind facilities to have an impact on some bat populations, but the level of impact is uncertain (reviewed by Barclay et al. 2007, Kunz et al. 2007, NRC 2007, Arnett et al. 2008). There have been high fatality rates of bats documented at some land-based wind facilities in eastern North America, with fatality rates ranging from 15 bats/MW/year to 41 bats/MW/year (reviewed in Kunz et al. 2007, Arnett et al. 2008). Species most vulnerable to collisions are migratory species that are most likely to venture out to sea during long-distance flights. In the northeastern United States, this includes three species of so called "tree bats" that roost solitarily and winter in the southern US including red bat (*Lasiurus borealis*), silver-haired bat (*Lasionycterus noctivagans*), and hoary bat (*Lasiurus cinereus*)(Cryan and Brown 2007, Arnett et al. 2008, von Oettingen 2011).

Offshore surveys are just being initiated for bats, but preliminary surveys suggest that some species, in particular red bat, are likely to be found offshore during fall migration (Cryan and Brown 2007, Johnson et al. 2010). There is a great deal of concern for bats in North America due to massive mortality events caused by the psychro-philic fungus (*Geomyces destructans*) leading to white-nosed syndrome that occurs in cave-dwelling bats that roost communally (Blehert et al. 2009).

5.2. Current U.S. Monitoring Requirements and Standards

To our knowledge, there are no standardized monitoring guidelines for ORED in the U.S. by any US federal agency (e.g. the US Fish and Wildlife Service [USFWS], BOEMRE). The USFWS voluntary guidelines for land-based wind turbines that cover topics such as preliminary evaluation and screening of sites, site characterization, field studies to document site wildlife conditions and predict potential impacts, post-construction fatality studies, and other pos-construction activities (USFWS 2011). For example, the land-based guidelines recommended a tiered approach which contains up to five iterative stages, with three stages related to pre-construction monitoring and two stages related to post-construction monitoring. Federal agencies such as the USFWS will make recommendations on monitoring plans for individual offshore developments, but these recommendations will vary from project to project and develop over time.

5.2.1. Under Current Offshore Renewable Energy Permits

Cape Wind Energy Project, Massachusetts

MMS and Cape Wind Associates developed a draft Avian and Bat Monitoring Plan for the Cape Wind Project, an offshore wind facility with 130 proposed turbines (MMS 2008c). They had a number of recommendations for pre-construction (tracking movements, travel corridors, and flight trajectories of terns and plovers in and around Nantucket Sound; tech effectiveness of anti-perching devices, radio telemetry, and acoustic monitoring devices to detect roseate terns, piping plovers, red knots, and bats in project area). Post-construction, the focus of monitoring efforts is: tracking movements, travel corridors, and flight trajectories of terns and plovers in and around Nantucket Sound; acoustic monitoring devices to detect roseate terns, piping plovers, red knots, and bats in project area; visual monitoring of effectiveness of anti-perching devices and altering these devices if needed; aerial surveys of overall bird abundance; and collision detection through use of TADS or other system; and establish a reporting system that will effectively and timely use the results of monitoring for adaptive management decisions). Specifics about monitoring guidelines for this project are still not available.

Verdant Power Roosevelt Island Tidal Energy project, New York

This project installed two underwater turbines (Verdant Power 2010). Most biological monitoring for this project focused on fish. However, limited avian monitoring included seasonal bird observations (visual surveys) for two years in spring and fall over 11 days. Birds observed were a mixture of waterfowl (scaup, ring-neck duck, mallard, Canada geese) cormorants, terns, and gannets. It appears there is little bird activity near this development to justify in-depth monitoring.

5.3. Current E.U. Monitoring Requirements and Standards for Offshore Renewable Energy

Monitoring guidelines in Europe vary among countries. Below are some examples of avian monitoring guidelines for wind farms in Europe.

Denmark

Extensive pre-construction monitoring took place for a number of offshore wind facilities. For example at Horns Rev (80 turbines, 160 MW, 20 km^2), preconstruction monitoring took place from Aug 1999 to April 2001 (14 surveys), while data were collected while the wind facility was under construction from Sept 2001 to April 2002 (4 surveys; Christensen et al. 2003). To assess the spatial distribution and abundance of birds, aerial surveys were conducted at an altitude of 76 m at 185 km/hr, with two observers (one on each side of plane). Transects were 2 km apart covering 821 km. Birds were recorded in three distance bands (44-163 m, 163-432 m, and 432-1000 m). Surveys were never conducted when wind speed >6 m/sec. Baseline survey protocols were virtually identical for Horns Rev 2 (Christensen et al. 2006) were virtually identical to Horns Rev, with much overlap in survey transects. Denmark no longer requires any post- construction monitoring of bird use at or near offshore wind facilities (T. Fox, pers. comm.). Pre-construction (1999-2002) aerial surveys at Rødsand were similar to protocols used at Horns Rev and Horns Rev 2. Radar was used to monitor pre- and post-construction movements of birds (primarily of waterfowl) at Rødsand (Desholm et al 2002) and at Nysted

(Desholm and Kahlert 2005). Denmark currently does not require post-construction monitoring of offshore wind farms (A. Fox, pers. comm.).

Germany

A series of survey methodologies are recommended by BSH (2007). Baseline large-scale surveys of the spatial distribution and abundance of birds are recommended for at least two consecutive annual cycles before construction begins. Post-construction – at least three years – up to 5 years – is recommended. BSH (2007) recommended both standardized ship-based surveys and aerial surveys to quantify the spatial distribution and abundance of birds. These ship-based surveys (3 to 4 km spacing between transects; 11-30 km/hr) have recommend line-transect methodology (300 m box with distance bins of 0-50, 50-100, 100-200, 200-300 m. For aerial surveys, they recommend 78 m flight altitude, 3- 5 km transect spacing, at least 500 km of transect, three observers (one main observer on each side of plane, and one observer on side where counting conditions are best to assess errors of main observers, with distance bins of 45-167 m (band width 122 m), 168-442 (275 m wide), and 443-1500m (1057 m wide) from the plane. Radar investigations are also recommended out to approximately 2.5 km from the radar unit. Their protocols also recommend visual observation and recording of flight calls to ground-truth radar data – this is recommended for two consecutive annual cycles (ca. 50 survey days, 900 survey hours spread throughout 24 annual cycle) for baseline studies and at least three years for post-construction monitoring plans.

United Kingdom

The UK is developing more offshore wind facilities than any other country in the world. Campyhusen et al. (2004) have made recommendations on standardized protocols for aerial and ship-based surveys – Maclean et al. (2009) summarized how these protocols were being followed. Camphuysen et al. (2004) recommended an area six times the size of the proposed wind facility be surveyed, but not all assessments surveyed an area that large. Camphuysen et al. (2004) recommended for ship-based surveys (Table 5.1): 300 m strip width line transects with distance bins of 0-50, 50-100, 100-200, 200-300, and 300 m+, no observations in sea state >4, survey time intervals of 1 or 5 min, ship speed of 18 km/hr, ship 20 100 m length with 10 m high viewing platform, two competent observers, survey transects 1-4 km apart; for aerial transects recommendations are: twin engine aircraft, high-wing, line-transects 2 km apart, flight speed 185 km/hr, 80 m altitude (often modified to 76 m), detection bands of 44-163 m, 164-432 m, and 433-1000 m), two trained observers per flight, GPS log position every five seconds, no observation in sea state >3. Maclean et al. (2009) found that pre-construction surveys for seven wind facilities met these criteria. However, many assessment surveys only sampled a small area (e.g., 1 km buffer at Thanet offshore wind farm). One concern of Maclean et al. (2009) was that many assessment surveys did not provide enough information in their methods section to determine in survey protocols were being met. The number of baseline surveys varied considerable among projects (see Table 6).

Table 6

Summary of avian baseline surveys conducted at UK wind farms (Maclean et al. 2009).

Wind Farm	Aerial Surveys	Boat-based Surveys
Gwynt y Mor	July-Aug 2004; Nov 2004-Feb 2005; May 2005	Monthly, Feb 2003-Mar 2005
Lincs	17 surveys between Nov 2003- Mar 2006	33 surveys between March 2004 – March 2006
Kentish Flats	1 survey	9 surveys from Oct 2001 to April 2002
West of Duddon Sands	19 surveys between Aug 2002 and March 2006	15 surveys between May 2004 and Sept. 2005
Greater Gabbard	8 surveys in the winters between Nov – Feb in 2004 and 2005	22 surveys between Feb 2004 to April 2006
London Array	11 surveys between Aug 2002 - Dec 2004	29 between Oct 2002 - to Feb 2005
Race Bank	14 surveys Nov 2004-Aug 2006	25 surveys between Dec 2005 and Nov 2007
Thanet	8 surveys during winters of 2004-05 and 2005-06	12 surveys from Nov 2004-Oct 2005

Table 7

Examples of international guidelines for avian monitoring duration and intensity during pre- and post-construction at offshore wind facilities from USFWS (2011).

Country	State/region	Technique	Pre- or Post-construction	Recommendation	Citation
Poland		Pre-construction: Transect population and species composition studies, MPPL studies, Intensity of airspace use by birds studies, Qualification of rare and average population species Postconstruction: Mortality monitoring	Pre- and Post-	Pre-construction duration: 1 year including all phenologic periods. Pre-construction frequency: Transect: Each transect controlled every 6 - 18 days. Post-construction duration: 3 years including all phenologic periods. Includes all four preconstruction modules listed above and mortality monitoring.	Polish Wind Energy Association. 2008.
United Kingdom		Aerial Survey	Pre- and Post-	Pre-construction and post-construction frequency and duration: Maximize the number of counts within the desired time period and by extending this time period for as long as possible. Survey for four years prior to construction and for four years after construction.	Maclean et al. 2006
United Kingdom		Remote techniques	Pre-, during, Post-	Pre-construction, post-construction and during construction frequency and duration: At least 7 full days (24 hour coverage) per month, in the peak periods (preferably not in a single block). This should cover the main migration periods (March-May and mid-July-November inclusive), the breeding season (May- initial surveys and screening, for at least 25 days per year. Baseline surveys should cover a minimum of 2 (preferably 3) annual cycles to achieve maximum quantification of inter annual variability, both during the baseline and post construction phases.	Desholm et al. 2004.
United		Aerial and ship-based	Pre- and Post-	Pre-construction and Post-construction frequency:	DEFRA 2005.

Kingdom		surveys		Surveys should relate changes in bird abundance to environmental factors including season, time of day, tidal influence and prey availability. Some effort should be made to collect data under different weather conditions. At least four flights undertaken during the winter, with counts carried out across the whole period if possible. Where breeding birds are present, at least three flights should be undertaken between May and July/August. Consider additional surveys for any other periods considered likely to be important (post-breeding, molting or spring/autumn passage). Winter surveys are considered to be mid-October to mid-March, summer breeding from late May to early August, late summer from late August to September and Autumn from mid-September to October. It is recommended that 1 to 2 ship-based surveys be undertaken each month during key periods. Pre-construction and post-construction duration: Data should be collected before the construction, up to several years after construction and, ideally, during construction. It is recommended that aerial and ship-based surveys be carried out for at least three years following construction and some monitoring may be required for the full lifetime of the development. Radar studies may be required resulting from any barrier effects. Further work may be required subject to the results of the initial monitoring period. Longer term monitoring will be needed to evaluate gradual or incremental changes,	

6. MONITORING REQUIRED FOR CURRENT U.S. OFFSHORE RENEWABLE ENERGY PROJECTS

The Federal Energy Regulatory Commission (FERC) has issued preliminary permits for 35 MHK (marine hydrokinetic) projects (tidal and wave) in the U.S. (Figure 2 and Table 8). All permits are for pilot projects designed to demonstrate the feasibility of the technology, and none are for utility-scale developments. FERC does not have a specific set of monitoring standards in place for hydrokinetic energy installations. Their MHK pilot project licensing procedures (FERC 2008) require the applicant to design and include a proposed monitoring plan in the draft license application and a revised monitoring plan in the final license application. That monitoring plan should address all resources that might be impacted.

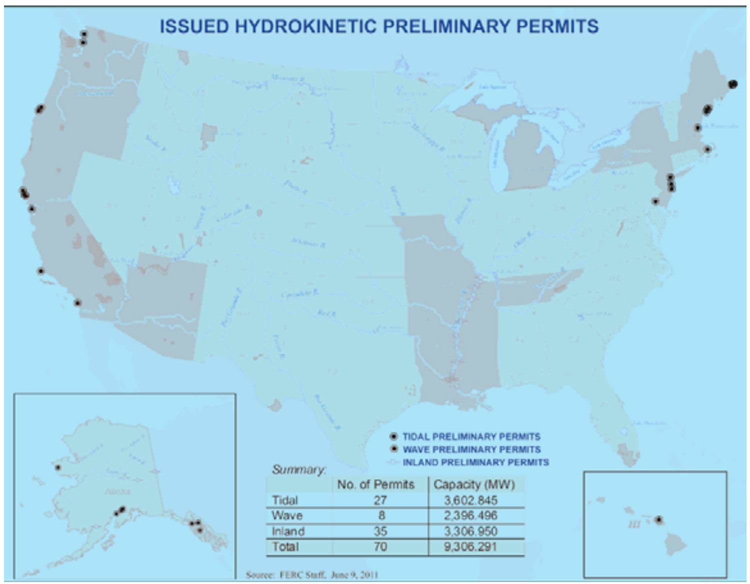


Figure 2. Current MHK Permits in the United States (http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp)

Table 8

FERC MHK Preliminary Permits Issued as of June 2011(http://elibrary.ferc.gov/idmws/search/fercgensearch.asp).

FERC Docket Number	Project Name	State	Waterway	Authorized Capacity (KW)	Issue Date	Expiration Date	Type
P- 13298	PORT CLARENCE	AK	PORT CLARENCE	300	05/08/09	04/30/12	Tidal
P- 13509	TURNAGAIN ARM TIDAL	AK	COOK INLET	2200000	02/05/10	01/31/13	Tidal
P- 13605	ICY PASSAGE TIDAL	AK	PACIFIC OCEAN	300	04/30/10	03/31/13	Tidal
P- 13606	GASTINEAU CHANNEL TIDAL	AK	GASTINEAU CHANNEL	400	04/30/10	03/31/13	Tidal
P- 12679	COOK INLET TIDAL ENERGY	AK	COOK INLET	1000	10/13/10	09/30/13	Tidal
P- 13821	EAST FORELAND TIDAL ENERGY	AK	COOK INLET	100000	03/11/11	02/28/14	Tidal
P- 13823	KILLISNOO TIDAL ENERGY	AK	KILLISNOO INLET	250	01/21/11	12/31/13	Wave
P- 12585	SAN FRANCISCO BAY TIDAL ENERGY PROJ	CA	SAN FRANCISCO BAY	10000	02/04/10	01/31/13	Tidal
P- 13377	FORT ROSS (SOUTH)	CA	PACIFIC OCEAN	5000	07/09/09	06/30/12	Wave
P- 13376	DEL MAR LANDING	CA	PACIFIC OCEAN	5000	07/09/09	06/30/12	Wave
P- 13378	FORT ROSS (NORTH)	CA	PACIFIC OCEAN	5000	07/09/09	06/30/12	Wave
P- 13679	SAN ONOFRE OWEG ELECTRICITY FARM	CA	PACIFIC OCEAN	3186000	10/29/10	09/30/13	Wave
P- 13521	OCEANLINX MAUI	HI	PACIFIC OCEAN	2700	11/25/09	10/31/12	Wave
P- 13828	CAPE COD TIDAL	MA	HOG ISLAND CHANNEL	20000	12/09/10	11/30/13	Tidal
P- 13329	TOWN OF WISCASSET TIDAL RESOURCES	ME	SHEEPSCOT RIVER	10000	05/28/09	04/30/12	Tidal

P-	13345	HOMEOWNER TIDAL POWER ELEC GEN	ME	KENNEBEC RIVER	60	07/01/09	06/30/12	Tidal
P-	13646	Damariscotta Tidal	ME	Damariscotta River	250	05/19/10	04/30/13	Tidal
P-	12704	HALF MOON TIDAL ENERGY	ME	PASSAMAQUODDY BAY	9000	12/03/10	11/30/13	Tidal
P-	12711	COBSCOOK BAY TIDAL ENERGY	ME	COBSCOOK RIVER	750	01/13/11	12/31/13	Tidal
P-	12680	WESTERN PASSAGE OCGEN	ME	ATLANTIC OCEAN	1200	01/13/11	12/31/13	Tidal
P-	13801	KENDALL HEAD TIDAL ENERGY	ME	ALTANTIC OCEAN	1200	01/13/11	12/31/13	Tidal
P-	13884	PENNAMAQUAN TIDAL POWER PLANT	ME	PENNAMAQUAN RIVER	21100	03/01/11	02/28/14	Tidal
P-	13503	GENERAL SULLIVAN AND LITTLE BAY BRI	NH	PISCATAQUA RIVER	0	09/30/09	08/31/12	Tidal
P-	13247	KINGSBRIDGE MARINA TIDAL ENERGY	NJ	MANASQUAN RIVER	40	12/12/08	11/30/11	Tidal
P-	13725	HIGHLANDS NEW JERSEY TIDAL ENERGY	NJ	SHREWSBURY RIVER	3000	01/11/11	12/31/13	Tidal
P-	13682	HOFFMAN'S MARINA TIDAL	NJ	MANASQUAN RIVER	200	01/11/11	12/31/13	Tidal
P-	13849	SALEM TIDAL ENERGY	NJ	SALEM RIVER	3000	05/02/11	04/30/14	Tidal
P-	12611	ROOSERVELT ISLAND TIDAL ENERGY	NY	EAST RIVER	5000	02/17/09	01/31/12	Tidal
P-	12718	WARDS ISLAND TIDAL POWER	NY	EAST RIVER	96	04/17/09	03/31/12	Tidal
P-	13730	ASTORIA TIDAL ENERGY	NY	EAST RIVER	2000	01/10/11	12/31/13	Tidal
P-	12665	ASTORIA TIDAL ENERGY	NY	EAST RIVER	200	01/10/11	12/31/13	Tidal
P-	12749	COOS BAY OPT WAVE PARK	OR	PACIFIC OCEAN	100000	08/10/10	07/31/13	Wave
P-	12743	DOUGLAS COUNTY WAVE & TIDAL ENERGY	OR	UMPQUA RIVER	3000	10/06/10	09/30/13	Wave

P-	12690	ADMIRALITY INLET TIDAL ENERGY	WA	PUGENT SOUND	1000	07/08/10	06/30/13	Tidal
P-	12687	DECEPTION PASS TIDAL ENERGY	WA	PUGENT SOUND	6400	08/04/10	07/31/13	Tidal

6.1. Verdant Power – Roosevelt Island Tidal Energy (RITE) Project, New York

The RITE project is a multi-phased demonstration tidal project located in the east channel of the East River in New York City, NY (Verdant Power 2010). The RITE project consists of open rotor bottom mounted turbines secured to the river bed with either a monopile or triframe foundation (Figure 3).

The first phase of the project tested a single device. Phase 2 of the project was recently completed, with six 35-kW bottom mounted turbines. Phase 3 is build-out to 30 turbines and 1 MW of total output, though it is still classified as a pilot project. The monitoring completed for Phase 2 and planned for Phase 3 focuses on fish and birds. Due to the project's inshore location, no monitoring for marine mammals or sea turtles was included in the plan (Verdant Power LLC 2010).

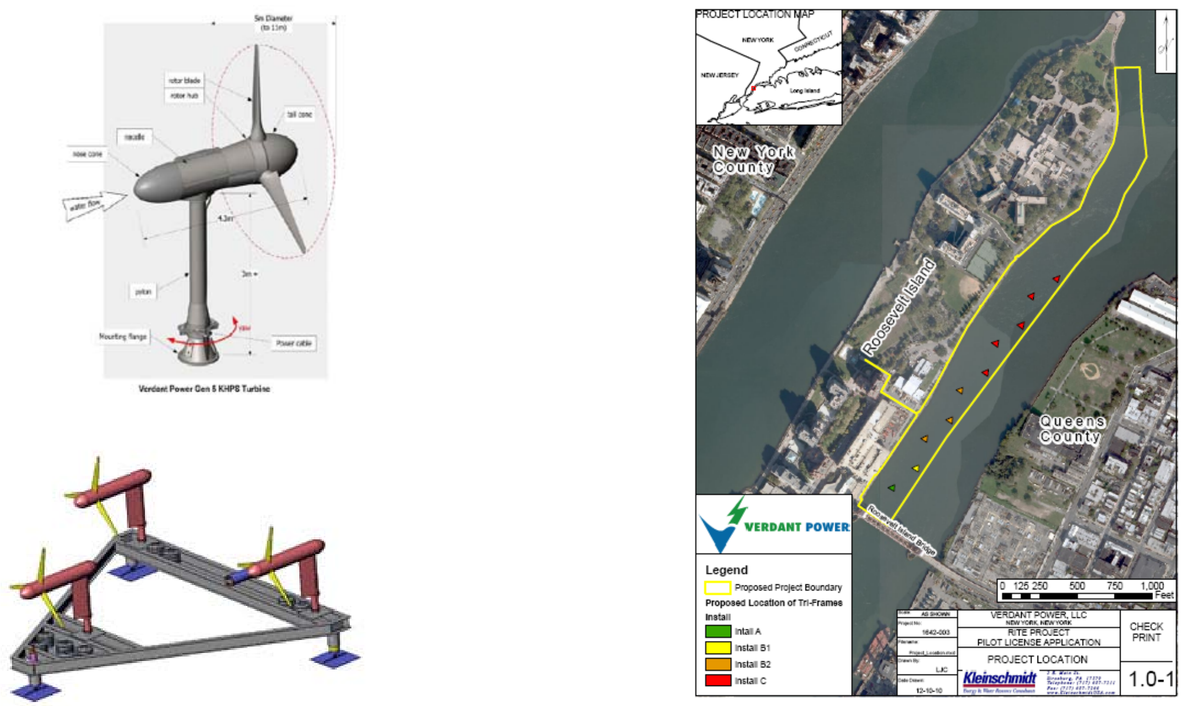


Figure 3. Monopile and Triframe Tidal Turbines Proposed for the Verdant Power – Roosevelt Island Tidal Energy (RITE) Project, New York. (Note: Triangles represent the location of each device and colors represent the phase of the project (green: first phase; yellow and orange: phase 2; red: phase 3)

The type, duration and frequency of monitoring planned differs for each phase of the project (Table 9). Because the RITE project was one of the very first MHK projects installed in the U.S., the monitoring planned developed for this project it may not serve as model for other MHK projects, however it does provide a useful starting point in identifying the type and scope of monitoring considered.

Table 9

Verdant Power – Roosevelt Island Tidal Energy (RITE) Project Monitoring (Verdant Power 2010).

Type of Monitoring	Description	Phase A: One turbine using a monopile foundation	Phase B-1: Three turbines on triframes	Phase B-2: Three to twelve turbines on triframes	Phase C: Up to thirty turbines total on triframes.
Seasonal Fixed Hydro-acoustics	-split beam transducers used to measure abundance, temporal and spatial location and size of aquatic targets -provide information on fish distribution, abundance, and behavior -deployed 24 hours a day,7 days a week for one month periods -Deployment during a known migration time -*Status/Findings:* Determined continuous data collection was not necessary, instead targeted use of technology during known periods of peak abundance is more appropriate	None proposed	None proposed.	1 year 2-split beam transducers between Sept 15th-Dec 15th	1 year 2-split beam transducers between Sept 15th-Dec 15
Seasonal Dual-Frequency Identification Sonar (DIDSON) Monitoring	-Purpose is to monitor fish interaction with device(s) -Provides real-time observation of fish behavior near turbines -Collected during known	For 1 year, 3 weeks during the window Sept 15th to Dec 1st	For 1 year, 3 weeks during the window Sept 15th to Dec 1st	Twice during 1 year for 3 weeks during Sept 15th to Oct 7th and Oct	None; Unless Phase B-2 indicates effects

	period of fish abundance -Limited deployment to 3 weeks because of biofouling -*Status/Findings:* Showed some avoidance behavior of fish approaching turbines – limited data set			15th to Dec 1st	
Seasonal Species Characterization Netting	–Species characterization trawls during slack tide -Mid-water research trawl -Deployed where hydroacoustics indicated fish are located -Once late spring, once in summer, and every other week from September 15-December 15 for all phases of project - *Status/Findings:* Trawl surveys attempted but suspended due to safety considerations	1 year Six days during the window Sept 15th-Dec15th	1 year Six days during the window Sept 15th-Dec15th	1 year Six days during the window Sept 15th-Dec15th	1 year Six days during the window Sept 15th-Dec15th
Tagged Species Detection	-Monitor for the presence of Rare, Threatened, and Endangered Species (esp. sea turtles) -4 hydrophones deployed -Install hydrophones in both channels to monitor for tagged fish (esp. shortnose and Atlantic sturgeon and striped bass) - *Status/Findings:* Deployment for 6 months yielded no observations – protocol abandoned by	April-Nov	April-Nov	Only if study continues	Only if study continues

	mutual agency consent				
Seasonal Bird Observations	– Purpose was to observe bird interactions and reaction to device(s) - focused on diving birds -Dawn to dusk observations of bird activity Status/Findings: -Pre- and post-deployment -3 year study, 290 hours of bird observation -Almost all sightings were of double crested cormorants or Canada geese	None proposed	1 year seasonal spring and fall for 11 days	2 years seasonal spring and fall for 11 days	None proposed
Underwater Noise Monitoring and Evaluation	- Purpose was to measure the noise signature of device(s) -Measurements taken by deployed hydrophones at varying distances from array	None proposed	1 year stationary for 1 month; 3 far field locations for one week	None proposed unless Phase B-1 indicates effects	1 year stationary for 1 month; 3 far field

6.2. Admiralty Inlet Pilot Tidal Project, Puget Sound, WA

The Admiralty Inlet Pilot Tidal Project is a research and demonstration project proposed by the Public Utility District No. 1 of Snohomish County, Washington. This proposed project includes the installation of two bottom-mounted, shrouded axial flow turbines (show in Figure 4). The turbines will stand 10 meters above the bottom and will be mounted to the sea floor using a submerged gravity foundation (Snohomish County Public Utility District No. 1 [PUD] 2009a). While this project will produce a modest amount of energy (approximately 1 megawatt (MW) of electrical energy at peak tidal currents), the primary purpose of the Project is to explore the feasibility of tidal energy as a generation resource.

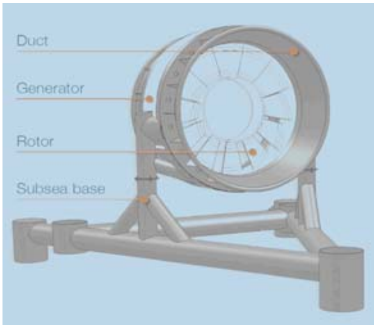


Figure 4 Bottom-Mounted, Shrouded Axial Flow Turbines Proposed for the Admiralty Inlet Pilot Tidal Project, Puget Sound, WA (Snohomish County PUD 2009).

The monitoring plan for this proposed project is presented in Table 10. Because the purpose of this demonstration project is in part to conduct research and obtain a greater understanding of this technology and its feasibility the monitoring plan proposed for this project includes a wider array of topic areas.

Table 10

Monitoring Plan Proposed for the Admiralty Inlet Pilot Tidal Project, Puget Sound, WA (Snohomish County PUD 2009a).

Pre-installation study plan – Marine Mammals and Marine Birds	
Baseline	–Analysis of existing historic data on killer whale migration and presence in study area
Passive acoustic monitoring:	•Two autonomous hydrophones two collect click data from harbor porpoises and delphinids •Shore-based hydrophone focused on Southern Resident killer whales with real-time data streaming •Collect data on ambient noise •Use vertical hydrophone array to opportunistically collect dive depth information
Field-based data collection	•Use land-based observers - 200+ hours to monitor killer whale movements and support boat-based surveys •Volunteer sighting network •Boat-based surveys –Observer and acoustic surveys of killer whales –Observe usage of nearest haul-out by Steller sea lions and harbor seals - Collect incidental information on presence of marbeled murrelet in study

	area during boat-based observations
Pre-Installation Study Plan - Aquatic Species	
Hydroacoustic fish assessment	•Vessel-mounted split beam hydroacoustic sonar •Daytime and nighttime, slack tide and maximum tide, different lunar cycles, in various seasons •First survey conducted in April 2009
Tagged fish assessment	•Employ acoustic receiver to detect acoustically-tagged fish (tagged by NOAA and POST) •Acoustic receiver deployed for at least one year
Post-Installation Proposed Monitoring	
Aquatic Species	−Paired multi-beam acoustic cameras to detect and observe marine species on either side of turbine −Relative abundance of fish and marine mammals −Underwater digital video cameras to species identification in near-turbine vicinity −Multi-beam and digital video monitoring for a full year after deployment −ROV video footage
Acoustic Monitoring	−Passive Acoustic data collection for marine mammals −Digital broadband hydrophone that streams data to shore
Benthic Habitat Monitoring	−ROV surveys around the base of turbine foundations and portions of subsea cable route −Concurrent with ROV deployments as part of operations and maintenance - at least twice annually

6.3. Ocean Power Technologies Wave Park -Reedsport, Oregon

The Ocean Power Technologies Wave Park proposed off the coast of Reedsport, Oregon consists of 10 point-absorber buoys (see Figure 5) to be sited in state waters (Reedsport OPT Wave Park, LLC 2010). The total capacity of this project is projected to equal 1.5 megawatts.

Figure 5 PowerBuoy Device Proposed for the Ocean Power Technologies Wave Park -Reedsport, Oregon (Reedsport OPT Wave Park, LLC 2010).

Table 11

Proposed Monitoring for the Ocean Power Technologies Wave Park -Reedsport, Oregon (Reedsport OPT Wave Park, LLC 2010).

Proposed Monitoring Before Deployment	
Baseline characterization	Shore-based observations of grey whale migration and other marine mammals conducted December 2007 - June 2008
Acoustic Emissions Characterization	In situ measurements of wave buoy at various sea states
Proposed Post-Deployment Monitoring	
Marine Mammals	– Establish shore-based observation station on 80-foot sand dune – Observe and track whale movements to determine whether there is a deflection around the array – Boat-based observations concurrently with other studies and maintenance/operations visits
Juvenile salmon monitoring	Beyond BACI design – Multimesh gillnets to capture fish at project site and two control sites ·Capture both juvenile and adult fish ·Calculate CPUE between sites ·Two sampling efforts per year in spring and fall – Gut contents analysis

	•Sample for juvenile salmon among predators caught with various gears •Four sampling efforts per year
Rockfish monitoring	Beyond BACI design – Sample for rockfish before and after installation at project sites and multiple control sites •4 times per year pre-installation •Sampling for 3 years post-installation to look for reef effects •Hook and line, multimesh gillnets, traps –Visual surveys from ROV or by SCUBA divers as part of operations and maintenance plan •Video camera recordings Every 3-4 months during first two years, and annually thereafter
Dungeness Crab	– Catch surveys with traps – First three years post-installation
Green Sturgeon	– Hydrophone receivers on project components to detect tagged fish
Flatfish and Invertebrates	– Beam trawl survey adjacent to array and at two control sites – Three times per year
Pelagic Fish and Invertebrates	SCUBA surveys to collect information on fish and invertebrates close to array
Biofouling community	– SCUBA analysis of biofouling – Identify and estimate abundance of biofouling species and other marine organisms – ROV surveys as part of maintenance
Avian	- Boat-based surveys –Standardized strip-transect sampling for birds at sea •Two 2-3 day periods of sampling/month for one year •Sampling project area and areas to north and south •Species-specific density estimates - - Radar sampling - Shore-based surveillance radar system •Relative numbers of birds active during day and night

	- Behavioral-Avoidance/Fatality Study −Seeking guidance from resource agencies

6.4. Cape Wind Construction and Operations Plan

The Cape Wind Energy Project proposed to be located in the federal waters of Nantucket Shoals and consist of 130 3.6 megawatt wind turbines with monopile foundations. The project will cover approximately 25 square miles in federal waters offshore Massachusetts with the maximum capacity to produce about 468 megawatts. The recently released Construction and Operations Plan outlines the monitoring requirements for this project before, during and after construction (Cape Wind Associates 2011). A summary of the approved monitoring scheme is presented in Table 12.

Table 12

Monitoring Proposed for the Cape Wind Energy Construction and Operation Plan (Cape Wind Associates 2011).

Pre-construction Monitoring	
Seafloor habitat and Benthic Community	• Video surveillance -3 pre-selected cable embedment segments within the 3 mile limit, and 3 segments on OCS •Each up to .5 miles in length •Video camera with GPS linkage towed along each of the routes •Review the videos for the following: -Presence and characterization of substrate -Presence and characterization of epibenthic invertebrates (especially lobster and crabs) -Presence and general characteristics of shellfish (especially scallops) -Evidence of lobster burrows, if visible -Presence and characterization of fish and habitat -Organisms identified to lowest practicable taxonomic level -Location of features • Aerial surveys of eelgrass beds in Lewis Bay -monitoring will include three additional paired monitoring sites in the OCS not outlined in monitoring plan Shellfish monitoring plan for cable area in Lewis Bay – shellfish samples will be taken for 1-2 days

Avian and Bat Monitoring	• Radio Tracking Study –Common terns and semi-palmated plovers tagged with radio transmitters and tracked by airplane • Acoustic Monitoring –Autonomous Recording Unit (ARU) set up on met tower to record bird calls • Bat Surveys –Passive bat monitoring system set up on met tower
During Construction	
Marine Mammal Monitoring	• Seismic Surveying : •500 m radius exclusion zone around any seismic survey vessel •NMFS approved observer will monitor the zone for marine mammals and sea turtles for 60 minutes prior to commencing or restarting surveys, during surveys, and for 60 minutes after surveys end •Seismic sound source will be shut down immediately if a marine mammal or sea turtle enters the zone and not restarted until the area has been clear for 60 minutes • Pile Driving: •750 m radius exclusion zone around each pile driving site for listed whales and sea turtles •Soft start will be required •Pile driving cannot occur during night hours •Summary of observed marine mammals and sea turtles, and observed injury or mortality within 24 hours of pile driving, and other observations within 48 hours of pile driving will be reported to NMFS and BOEMRE
Post-Construction Monitoring	
Seafloor habitat and Benthic Community	• Monitor benthic community recovery along cable route • Monitor scour mats and cables periodically to determine whether deterioration is occurring
Avian and Bat Monitoring	• Anti-Perching Monitoring –Determine effectiveness of perching deterrents on turbine platforms –Video cameras placed on ESP and two turbine towers • Abundance and Spatial Distribution studies –19 annual aerial surveys to allow for comparison with pre-construction surveys

	–Altitude of 250 feet / 76 meters –Birds identified along 16 transects 7500 feet apart • Acoustic Monitoring –Acoustic microphones placed on 10 monopoles and ESP –Record bird calls around wind farm 24/7 May-October, and three 24-hour intervals per month November – April • Radio Tracking –Document movements and locations of Roseate Terns and Piping Plovers –8-12 animals per species –Receiver set up on ESP • Thermal Animal Detection Systems (TADS) –Installation on two turbines post-construction to monitor any bird collisions –Monitoring for a minimum of three years

7. CONCLUSIONS

Overall, the literature review has found that, while many types of monitoring protocols exist and are currently employed, there are few standards for monitoring within any of these subject areas. While there is considerably more documentation of offshore wind energy projects than marine hydrokinetic projects, because there have been many more offshore wind energy projects developed within the last decade, monitoring data for any offshore renewable energy project are sparse. Within Europe, despite the proliferation of offshore wind facilities, most monitoring for effects does not follow any recognized standard, and there is little consistency in the data collected at each site. There have been attempts to make some recommendations for monitoring protocols, and Germany has adopted standards for monitoring Offshore Renewable Energy Developments (ORED). Existing monitoring practices are also inconsistent between countries. Within the United States, most other offshore development industries, including the offshore oil and gas industry, do not have standardized protocols for monitoring the effects of these activities. There are currently no specified protocols for protected marine species monitoring and mitigation for potentially harmful activities in U.S. waters. Many other potential effects of offshore activities, such as the effects of noise, or the disturbance caused by the installation of a device, appear to be monitored inconsistently if at all.

For any type of monitoring, it is critical to conduct baseline assessments that provide sufficient information to be compared with construction and post-construction monitoring data. These assessments should employ the same methods as later monitoring in order to compare data and detect changes in the resource being studied. It is also important that data are collected post-construction over a sufficient time period to detect effects that may not be immediately apparent. In collecting data for the purposes of monitoring, it is essential to consider both spatial and temporal variation. Many studies conducted to date measuring environmental effects from offshore renewable energy projects employ a Before-After-Control-Impact (BACI) design, which allows for a control area against which to compare spatial and temporal effects. Some authors within the literature have recommended a Beyond BACI design, which allows for multiple control sites to account for natural spatial variation. There is no agreement in how many control sites should be used, nor does there appear to be consistency in the amount of data collected, for how long and in what time periods.

The key findings from each of the topic areas are summarized below. These findings as well as other material included in this document will be used going forward to develop the standardized protocols in Year 2 of the project.

Benthic Habitat and Resources

Benthic surveys involve determining changes to biotic and abiotic features of the seafloor. Some of the techniques commonly used for baseline surveys include: geophysical surveys; underwater video/photography surveys; grab samples; beam trawls; and optical backscatter sensors or turbidity sensors. Underwater video is an effective and efficient method for monitoring hard bottom flora and fauna, as well as monitoring reef effects on the structures, while grab samples are more appropriate for soft-bottom substrates. Beam trawls have often been used in addition to underwater video or photography surveys for sampling the epibenthos.

Most studies of offshore renewable energy projects have used baseline surveys to design additional post-construction sampling projects that monitor both large- and small-scale effects, generally using the techniques discussed above. Large scale effects are changes across the study area, while small-scale effects are at the individual devices. For the most part, monitoring of small-scale effects took place more often and within a defined radius of the devices. When taking samples, there is some consensus in the literature that at least three samples should be taken from each sampling station. Most of the studies also emphasized the importance of establishing biotic-abiotic linkages on a spatial scale to better predict effects.

Fish and Fisheries

There are relatively well-established techniques for monitoring fish distribution and abundance; trawl surveys have been used for many years in both the U.S. and Europe to establish stock assessments. Trawl surveys can be used on a large scale to collect baseline data and to evaluate changes to abundance and distribution of fish around offshore renewable energy devices. Trawl surveys are best suited to assessing demersal and benthic species; acoustic surveys, which are more appropriate for pelagic species, should be done in conjunction with trawl surveys. For commercially valuable invertebrates such as lobster, a ventless trap survey can be used to assess distribution and abundance.

Noise effects on fish are not well understood. Surveys of distribution and abundance can be used to assess the effects of operational noise, while acoustic or catch surveys can be used to evaluate the effects of construction noise. The effects of EMF are even less well understood; these have been studied by various catch studies using nets or traps, including mark-recapture studies, and by mesocosm studies. Acoustic monitoring and video monitoring, perhaps in tandem, can be effective for monitoring blade strikes from tidal energy devices; both were used for the Verdant Power tidal energy project (Verdant Power 2010). Reef effects on turbines have been monitored in a variety of ways, including underwater video on ROVs or by divers, and by acoustic monitoring. With the exception of reef effects, these effects have been little studied, and thus there is no consensus of the best methods by which to monitor them.

Studies of wind farms in Europe have used all of the above-mentioned techniques to study possible effects to fish, although there is little consistency in which are used, and no consistent protocols about how much data are collected and over what time period. Again, Germany is the exception, requiring at least two years of baseline data, and monitoring every other year for five years during the operational phase, with specifications about the numbers of hauls and the sizes and distances of reference areas (BSH 2007).

There are no standards in place for monitoring fishing activity. Within the U.S., various types of data are collected by NMFS that are often used for monitoring fisheries, but these lack a reliable spatial component. Interviews and surveys are sometimes used, and have been used in the U.K., to determine changes to fishing activities and perceptions to changes.

Marine Mammals and Sea Turtles

Baseline assessments and post-construction monitoring of both marine mammals and sea turtles can be conducted using vessel-based surveys and aerial surveys. Passive acoustic monitoring (PAM) can be used for marine mammals to detect individual animals within a given area, but they are expensive and are only able to definitively identify a few species. Passive acoustic monitoring can be towed behind a vessel conducting shipboard visual surveys as a means of groundtruthing and supplementing the visual data. Photo-identification and tagging are also used in monitoring marine mammals to study individual animals.

During pre-construction seismic surveying and pile-driving activity in the construction phase, the Cape Wind project is required to have a monitoring zone with a NMFS-approved observer who will observe whether marine mammals and sea turtles come within a certain distance of the activity, requiring operations to be shut down until the animal leaves the vicinity. This serves as both a monitoring and mitigation measure, and similar measures are likely to be required for other offshore renewable energy projects permitted within the United States.

Avian

There are a number of methods used for monitoring the spatial distribution and abundance of birds. Ship-based surveys and aerial surveys are commonly used; ship-based surveys allow for a fine level of detail, but can be expensive and slow, requiring more time to cover a large geographical area. Aerial surveys allow for more coverage of a larger geographic area in a shorter period of time, but do not always allow for identification to the species level, can cause disturbance, and may underestimate bird numbers. High definition video surveys are also now being used along with more traditional visual surveys. Radar studies can be used to assess distribution and abundance of birds in a potential wind farm site on a fixed platform. Radar may also be useful in assessing collisions with the turbine. Acoustic surveys are another methodology that could be used to detect birds at night, particularly to assess collision risk; there is little experience with this technology in the offshore environment. Infrared cameras are another technology that has been used in Europe to assess collision risk, although this method may not be cost effective.

Monitoring standards in Germany call for two years of baseline data, and at least three, preferably five, years of post-construction monitoring. The standards require both ship-based and aerial surveys to monitor distribution and abundance. Likewise, monitoring at wind farms in the U.K. has employed both ship-based and aerial monitoring with varying levels of each.

LISTS OF REFERENCES

ABPmer Ltd, et al., 2010. A Further Review of Sediment Monitoring Data. Commissioned by COWRIE Ltd (project reference ScourSed-09), 115 pp.

Addis, P., A. Cau, E. Massutí, P. Merella, M. Sinopoli, and F. Andaloro. 2006. Spatial and temporal changes in the assemblage structure of fish associated to fish aggregation devices in the Western Mediterranean. *Aquatic Living Resources*, 19: 149-160.

Allen, B. M., and R. P. Angliss. 2010. *Alaska Marine Mammal Stock Assessments, 2009*. NOAA Technical Memorandum NMFS-AFSC-206.National Marine Fisheries Service, Seattle, WA.

AMEC Wind Energy. 2002. Lynn Offshore Environmental Impact Assessment.

Arnett, E.B, W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A.Jain, G.D. Johnson, J. Kerns, R.K. Koford, C. P. Nicholson, T.J. O'Connell, M.D. Piorkowski, and R. D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. *Journal of Wildlife Management,* 72:61-78.

Bachmann, S. and D.S. Zrnic. 2007. Spectral density of polarimetric variables separating biological scatterers in the VAD display. *Journal of Atmospheric and Oceanic Technology*, 24: 1186

Baerwald, E. F., G. H. D'Amours, B. J. Klug, and R. M.R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. *Current Biology,* 18:695-696

Bailey, H., B. Seniro, D. Simmons, J. Rusin, G. Picken, and P. M. Thompson. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effect on marine mammals. *Marine Pollution Bulletin,* 60:888-897.

Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. *Canadian Journal of Zoology*, 85:381-287.

Barlow, J., M. C. Ferguson, E. A. Becker, J. V. Redfern, K. A. Forney, I. L. Vilchis, P. C. Fiedler, T. Gerrodette, and L. T. Balance. 2009. *Predictive Modeling of Cetacean Densities in the Eastern Pacific Ocean*. NOAA Tech Memo NMFS-SWFSC-444. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA.

Barrow Offshore Wind Ltd. 2009. Barrow Offshore Wind Farm Post-Construction Monitoring Report. DONG Energy, Copenhagen, Denmark.

Becker E. A., K. A. Forney, M. C. Ferguson, D. G. Foley, R. C. Smith, J. Barlow, and J. V. Redfern. 2010. Comparing California Current cetacean-habitat models developed using in situ and remotely sensed sea surface temperature data. *Marine Ecology Progress Series,* 413:163–183.

Bergman, M., G. Duineveld, and P.V. Hof. 2008. Interim Report: Benthos Recruitment T1. Report OWEZ_R_262_T1_20080222 draft, 49 pp.

Birklund, J. and A.H. Petersen. 2004. Development of the fouling community on turbine foundations and scour protections in Nysted Offshore Wind Farm, 2003. Energi E2 A/S.

Blehert, D.S., A.C. Hicks, M. Behr, M. U. Meteyer, B.M. Berlowski-Zier, E. L. Buckles, J. T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat White-nose Syndrome: An emerging fungal pathogen? *Science*, 323:227.

Blew, J., M. Hoffmann, G. Nehls and V. Hennig. 2008. Investigations of the bird collision risk and the responses of harbor porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted. Report funded by German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Bloor, P. and A. Wratten. 2006. Aerial surveys of waterbirds in strategic wind farm areas: 2004/05 Final Report. Department of Trade and Industry DTI/Pub 8298, UK.

Boehlert, G. W. and A. B. Gill. 2010. Environmental and ecological effect of ocean renewable energy development - a current synthesis. *Oceanography,* 23(2):64-77.

Boehlert, G.W., G.R. McMurray, and C.E. Tortorici, editors. 2008. *Ecological Effects of Wave Energy Development in the Pacific Northwest*. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-92.

Borberg, J.M., L.T. Balance, R.L. Pittman, and D.G. Ainley. 2005. A test for bias attributable to seabird avoidance of ships during surveys conducted in the tropical Pacific. *Marine Ornithology*, 33:173-179.

Borja, A., A.B. Josefson, A. Miles, I. Muxika, F. Olsgard, G. Phillips, J.G. Rodríguez, and B. Rygg. 2007. An approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. *Marine Pollution Bulletin,* 55: 42-52.

Bouma, S., and W. Lengkeek. 2009. Development of underwater flora- and fauna communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ). Report nr 08-220. Bureau Waardenburg bv, Nordzeewind, 46 pp.

Brandt, M. J., A. Diederichs, K. Betke, and G. Nehls. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series,* 421:205-216.

Briggs, K.T., W. B. Tyler, and D.B. Lewis. 1985. Comparison of ship and aerial surveys of birds at sea. *Journal of Wildlife Management,* 49:405-411.

Brown, C.J., and J.S. Collier. 2008. Mapping benthic habitat in regions of gradational substrata: An automated approach utilising geophysical, geological, and biological relationships.

Estuarine Coastal and Shelf Science, 78: 203-214.

Brown, R.G.B., Nettleship, D.N., Germain, P., Tull, C.E., and Davis, T. 1975. *Atlas of eastern Canadian seabirds*. Ottawa, Can. Wildl. Serv.

Buckland, S.T. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford, U.K.: Oxford University Press.

Buckland, S.T. 2004. *Advanced Distance sampling.* Oxford, U.K.: Oxford University Press.

Bundesamt für Seeschifffahrt und Hydrographie [BSH]. 2007. *Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment* (StUK 3). BSH-Nr. 7003, Bundesamt für Seeschifffahrt und Hydrographie, Hamburg and Rostock, Germany. Available online from: http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf

Burger, J., C. Gordon, J. Lawrence, J. Newman, G. Forcey, and L. Vlietstra. 2011. Risk evaluation for federally listed (roseate tern, piping plover) or candidate (red knot) bird species in offshore waters: A first step for managing the potential impacts of wind facility development on the Atlantic Outer Continental Shelf. *Renewable Energy*, 36: 338-351.

Burt, L., E. Rexstad, and S. Buckland. 2009. Comparison of visual and digital aerial survey results of avian abundance for Round 3, Norfolk Region. COWRIE Ltd., United Kingdom.

Caltrans. 2001. Fisheries Impact Assessment: San Francisco – Oakland Bay Bridge East Span Seismic Safety Project, Pile Installation Demonstration Project. Caltrans Contract 04A0148.

Camphuysen, C.J., A.D. Fox, M.F., Leopold., I.K. Petersen. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore winds in the U.K. A comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments. Koninklijk Nederlands Instituut Onderzoek der Zee Report commissioned by COWRIE.

Cape Wind Associates, LLC. 2011. Cape Wind Energy Project, Nantucket Sound, MA Construction and Operations Plan. Prepared for Submission to: Bureau of Ocean Energy Management, Regulation and Enforcement. Prepared by: ESS Group, Inc.; Ocean Surveys, Inc.; SgurrEnergy, Inc. Project No. E159-504.1. February 4, 2011. 171 pp.

Carey, J.M., and M.J. Keough. 2002. The variability of estimates of variance, and its effect on power analysis in monitoring design. *Environmental Monitoring and Assessment,* 74: 225-41.

Carretta, J. V., K. A. Forney, M. S. Lowry, J. Barlow, J. Baker, D. Johnston, B. Hanson, R.L. Brownell Jr.m J. Robbins, D.K. Mattila, K. Ralls, M. M. Muto, D. Lynch, and L. Carswell. 2010. *U.S. Pacific Marine Mammal Stock Assessments: 2009*. NOAA

Technical Memorandum NMFS-SWFSC-453.National Marine Fisheries Service, La Jolla, CA.

Carstensen, J., O. D. Henriksen, and J. Teilmann. 2006. Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). *Marine Ecology Progress Series,* 321:295-308.

CEFAS. 2004. Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements.

CEFAS. 2010. Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA License Conditions.

CETAP (Cetacean and Turtle Assessment Program, University of Rhode Island). 1982. A Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic Areas of the U. S. Outer Continental Shelf, Final Report. Contract AA551-CT8-48.Bureau of Land Management, Washington, DC.

Christenesen, T.K., J.P. Hounisen, I. Clausager, and I.K. Petersen. 2004. Visual and radar observations of birds in relation to collision risk at the Horns Rev. offshore wind farm. Annual status report 2003. Report commissioned by Elsam Engineering A/S 2003. NERI Report. Ronde, Denmark: National Environmental Research Institute.

Christensen, T.K., I. Clausager, and I.K. Petersen. 2003. Base-line investigations of birds in relation to an offshore wind farm at Horns Rev. NERI Report, Denmark.

Christensen, T.K., I.K. Petersen, and A. D. Fox. 2006. Effects on birds of the Horns Rev 2 offshore wind farm: Environmental Impact Assessment. NERI Report.

Clark, N.A. 2006. Tidal barrages and birds. *Ibis*, 148:152-157.

Clarke, K.R., and R.N. Gorley. 2006. Primer-E, version 6. Plymouth, UK.

Clausen, K. T., M. Wahlberg, K. Beedholm, S. Deruiter, and P. T. Madsen. 2010. Click communication in harbour porpoises *Phocoena phocoena*. *Bioacoustics,* 20:1-28.

Cranswick, P., C. Hall and L. Smith. 2003. Aerial surveys of birds in proposed strategic areas for offshore windfarm development, Round 2: preliminary report, winter 2003/03. Wildfowl and Wetlands Trust Research Report, Slimbridge, Gloucestershire, UK.

Crawford R.L. and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology,* 72:380–388.

Cryan, P.M., and A.C. Brown. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. *Biological Conservation* 139(1-2): 1-11.

Daan, R., M. Mulder, and M.J.N. Bergman. 2009. Impact of windfarm OWEZ on the local macrobenthos community. Report OWEZ_R_261_T1_20091216, 77 pp.

David, J. A. 2006. Likely sensitivity of bottlenose dolphins to pile-driving noise. *Water and Environment Journal,* 20:48-54.

de Lestang, S., N. Caputi, J. How, R. Melville-Smith, A. Thomson, and P. Stephenson. 2011. Draft Stock Assessment for the West Coast Rock Lobster Fishery. Government of Western Australia, Department of Fisheries.

DEFRA. 2005. Nature Conservation Guidance on Offshore Windfarm Development - A guidance note on the implications of the EC Wild Birds and Habitats Directives for developers undertaking offshore windfarm developments. Available at: http://webarchive.nationalarchives.gov.uk/20080915101357/http://www.defra.gov.uk/wildlife -countryside/ewd/windfarms/index.htm

Degraer, S., R. Brabant, and B. Rumes. (Eds.). 2010. Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. 184 pp. + annexes.

Degraer, Steven, and R. Brabant, (Eds.). 2009. *Offshore wind farms in the Belgian part of the North Sea: State of the art after two years of environmental monitoring*. Chapter 12: Recommendations for a future monitoring of wind farms in Belgium's marine waters. Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. pp. 275-279.

Derweduwen, J., S. Vandendriessche, and K. Hostens. 2010. Monitoring of the effects of the Thorntonbank and Bligh Bank wind farms on the epifauna and demersal fish fauna of soft-bottom sediments: Thorntonbank: status during construction (T2), Bligh Bank: status during construction (T1). In: Degraer, S., R. Brabant, & B. Rumes. (Eds.) 2010. *Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability.* Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. pp. 105-131

Desholm, M. 2003. Thermal Animal Detection System (TADS). Development of a method for estimating collision frequency of migrating birds at offshore wind turbines. National Environmental Research Institute. NERI Technical Report 440. Rønde, Denmark: National Environmental Research Institute.

Desholm, M. 2005. TADS investigations of avian collision risk at Nysted offshore wind farm. NERI Report, 2005

Desholm, M. 2005a. Preliminary investigations of bird-turbine collisions at Nysted offshore wind farm and final quality control of Thermal Animal Detection System (TADS); autumn 2003 and spring 2004. NERI Report. Ronde, Denmark: National Environmental Research Institute.

Desholm, M. 2005b. TADS investigations of avian collision risk at Nysted offshore wind farm, autumn 2004. NERI Report. Ronde, Denmark: National Environmental Research Institute.

Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. *Biology Letters,* 1:296–298.

Desholm, M.D., A.D. Fox, and P. D. Beasley. 2004. Best practice guidance for the use of remote techniques for observing bird behaviour in relation to offshore wind farms. Cowrie – Remote 05-2004

Desholm, M.D., A.D. Fox, P.D.L. Beasley and J. Kahlert. 2006. Remote techniques for counting and estimating the number of bird-wind turbine collisions at sea: a review. *Ibis*, 148: 76-89.

Dhanju, A. and J. Firestone. 2008. A framework for regulation of offshore wind power in Delaware state waters. Unpublished report, University of Delaware College of Marine and Earth Studies.

Diaz, R.J., M. Solan, and R.M. Valente. 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. *Journal of Environmental Management,* 73: 165-181.

Diederichs, A., T. Grünkhorn, and G. Nehls. 2008. Offshore wind farms—disturbance or attraction for harbour porpoises? First results of T-POD investigations in Horns Rev and Nysted. Pp. 42-49 in: P.G.H. Evans (ed.). *Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts*. ECS Special Publication Series No. 49, European Cetacean Society, Caeernarfon, Gwynedd, UK.

Dierschke, J. 1989. Automatisch-akustische erfassung des nächtlichen vogelzuges bei Helgoland im sommer 1987. Vogelwarte 35: 115–131.

DoN (Department of the Navy). 2009a. Report on the OPNAV N45 Marine Mammal Monitoring Workship; R. David Thomas Executive Conference Center, Duke University, Durham, NC; February 19-20, 2009.U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, DC.14 pp.

DoN (Department of the Navy). 2009b. *United States Navy Integrated Comprehensive Monitoring Program*. U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, DC.50 pp.

DONG Energy 2006. *Danish Offshore Wind - Key Environmental Issues*. Chapter 5: Fish. DONG Energy, Vattenfall, the Danish Energy Authority and The Danish Forest and Nature Agency, Denmark.

Drewitt, A. L, and R. H.W. Langston. 2006. Assessing the impacts of wind farms on birds. *Ibis*, 148:29-42.

Drewitt, A. L., and R. H. W. Langston. 2008. Collision effects of wind-power generators and other obstacles on birds. *Annals of New York Academy of Sciences,* 1134:233-236.

Eastwood, E. 1967. *Radar Ornithology*. London: Methuen Press.

Edrén, S. M. C., S. M. Andersen, J. Teilmann, J. Carstensen, P. B. Harders, R. Dietz, and L. A. Miller. 2010. The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. *Marine Mammal Science,* 26:614-634.

Edŕen, S.M.E., J. Teilmann, R. Dietz, and J. Carstensen. 2004. Effects from the Construction of Nysted Offshore Wind Farm on Seals in Rødsand Seal Sanctuary Based on Remote Video Monitoring. Technical report to Energy E2 A⁄ S. National Environmental Research Institute, Roskilde.

Emu, Ltd, 2006. Kentish Flats Windfarm Development: Macrobenthic ecology study - 2005; Final Report 2006. Southampton, UK. 270 pp.

Engås, A.; S. Lokkeborg, E. Ona, and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Canadian Journal of Fisheries and Aquatic Sciences*, 53: 2238-2249.

ESS Group, Inc., 2011. Cape Wind Energy Project: Construction and Operations Plan, Appendix H: Selected Regulatory Permits and Approvals and Correspondence. Cape Wind Associates, LLC. 163 pp.

Evans, W.R. 1998. Applications of acoustic bird monitoring for the wind power industry. From Proceedings from the National Avian-Wind Power Planning Meeting III. San Diego, California, May 1998.

Evans, W.R., and K.V., Rosenburg. 2000. Acoustic monitoring of night-migrating birds: a progress report. In: Bonney, R.E., Jr., D.N. Pashley, and R. Cooper (eds), *Strategies for Bird Conservation: Creating the Partners in Flight Planning Process.* Proc. 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proc. RMRS-P-16. Ogden, UT: U.S. Dep. Agr. Forest Service, Rocky Mountain Research Station.

Fabi, G.; Grati, F; Puletti, M; Scarcella, G. 2004. Effects on fish community induced by installation of two gas platforms in Adriatic Sea. *Mar Ecol Prog Ser,* 273: 187-197.

Farnsworth, A. 2005. Flight-call and their value for future ornithological studies and conservation research. *Auk*, 122:733-746

Farnsworth, A. and R. W. Russell. 2007. Monitoring flight calls of migrating birds from an oil platform in the Gulf of Mexico. *Journal of Field Ornithology*, 78:279-289.

Farnsworth, A. and R.W. Russell. 2005. Evaluation of a method for monitoring audible fall bird migration traffic over platforms. Pages 247-256. In: *Interactions Between Migrating*

Birds and Offshore Oil and Gas Platforms in the Northern Gulf of Mexico. R.W. Russell, Ed. Mineral Management Service publication 2005-009.

Farnsworth, A., S. A. Gauthreaux, JR., and D. Van Blaricom. 2004. A comparison of nocturnal call counts of migrating birds and reflectivity measurements on Doppler radar (WSR-88D). *Journal of Avian Biology*, 35:365-369.

Fechhelm, R.G., W.B. Griffiths, B.E. Haley, and M.R. Link. 2004. *Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2003*. Report for BP Exploration (Alaska) Inc. by LGL Alaska Research Associates, Inc., Anchorage, Alaska. 75 p.

FERC (Federal Energy Regulatory Commission). 2008. Licensing Hydrokinetic Pilot Projects. FAQs. April 14, 2008. Federal Energy Regulatory Commission, Washington, DC.

FERC, 2006. Title 18: Conservation of Power and Water Resources Chapter 1: Federal Energy Regulatory Commission, Department of Energy, Part 5: Integrated license application process. http://www.access.gpo.gov/nara/cfr/waisidx_06/18cfr5_06.html; Last accessed 7/10/11.

FERC, 2010. *Reedsport OPT Wave Park Settlement Agreement*. FERC No. 12713, Douglas County, Oregon. 263 pp.

Ferguson, M. C., J. Barlow, P. Fiedler, S. B. Reilly, and T. Gerrodette. 2006a. Spatial models of delphinid (family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. *Ecological Modeling*, 193:645-662.

Ferguson, M. C., J. Barlow, S. B. Reilly, and T. Gerrodette. 2006b. Predicting Cuvier's (*Ziphius cavirostris*) and *Mesoplodon* beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. *Journal of Cetacean Research and Management*, 7:287–299.

Florida Fish and Wildlife Conservation Commission. 2006. *Draft: Guidelines for the protection of marine animals during the use of explosives in the waters of the state of Florida*. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.

Forney, K.A. 2000. Environmental models of cetacean abundance: reducing uncertainty in population trends. *Conservation Biology* 14:1271-1286.

Fox, A.D., M. Desholm, J. Kahlert, T.K. Christensen, and I.K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. *Ibis*, 148:129-144.

Frid, C.L.J., 2011. Temporal variability in the benthos: Does the sea floor function differently over time? *Journal of Experimental Marine Biology and Ecology*, 400: 99-107.

Garthe, S. and O. Hüppop. 1999. Effect of ship speed on seabird counts in areas supporting commercial fisheries. *Journal of Field Ornithology*, 70:28-32.

Geomarine, Inc. 2010. Ocean/wind power ecological baseline studies; January 2008 – December 2009, Volume II: Avian Studies. New Jersey Department of Environmental Protection, Office of Science, New Jersey.

Gill, A.B. 2005. Offshore renewable energy: Ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology,* 42: 605-615.

Gill, A.B., I. Gloyne-Phillips, K.J. Neal, and J.A. Kimber. 2005. COWRIE 1.5 Electromagnetic Fields Review: The Potential Effects of Electromagnetic Fields Generated by Sub-Sea Power Cables Associated with Offshore Wind Farm Developments on Electrically and Magnetically Sensitive Marine Organisms—A Review. COWRIE Ltd. (Collaborative Offshore Wind Energy Research into the Environment) EM Field- 06-2004, 128 pp. Available online at: http:// www.thecrownestate.co.uk/newscontent/92_ electromagnetic_fields_phase_1.5

Gill, A.B., Y. Huan, I. Gloyne-Phillips, J. Metcalfe, V. Quayle, J. Spencer, and V. Wearmouth. 2009. EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. COWRIE / Cranfield University / CEFAS, CIMS, CMACS (Center for Marine And Coastal Studies, Ltd).

Gill, J.P., C. Kemsley and D. Sales. 2002. The potential ornithological impact of the proposed Kentish Flats offshore wind farm. Report to GREP UK Marine Ltd., UK.

Gould, P.J. and D.J. Forsell. 1989. Techniques for shipboard surveys of marine birds. USDI, Fish and Wildlife Service Technical Report 25, Washington, D.C.

Grecian, W. J., R. Inger, M. J. Attrill, S. Bearhop, B. J. Godley, M. J. Witt, and S. C. Votier. 2010. Potential impacts of wave-powered marine renewable energy installations on marine birds. *Ibis*, 152:683-697.

Griffin, L., E. Rees, and B. Hughes. 2010. The migration of Whooper Swans in relation to offshore wind farms. The Wildfowl and Wetlands Trust for COWRIE Ltd.,

Grift, R.E., A.S. Couperus, and M.S. Ybema.. 2003. Base line studies North Sea wind farms: strategy of approach for pelagic fish. RIVO-Netherlands Institute for Fisheries Research. Report RKZ-1273. 20 pp.

Grift, R.E. and N. Tien. 2003. Strategy of Approach Demersal Fish Fauna. RIKZ report 9M9237.01. 16 pp.

Hamilton, P. K., A. R. Knowlton, and M. K. Marx. 2007. Right whales tell their own stories: the photo-identification catalog. Pp. 75-104 in: S. D. Kraus and R. M. Rolland, eds. *The Urban Whale: North Atlantic Right Whales at the Crossroads*. Harvard University Press, Cambridge, MA.

Heinig, C.S., and B.P. Tarbox. 2000. Pre- and post-dredge survey and relocation of the American lobster, *Homarus americanus*, population in Portland Harbor, Maine. Portland

Harbor Dredge Committee and Casco Bay Estuary Project.

Henfridsson, U., V. Neimane, K. Strand, R. Kapper, H. Bernhoff, O. Danielsson, M. Leijon, J. Sundberg, K. Thorburn, E. Ericsson, and K. Bergman. 2007. Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak. *Renewable Energy*, 32: 2069–2084.

Hexter, R. 2009. High resolution video survey of seabirds and mammals in the Maray Firth, Hastings, West Isle of Wight and Bristol Channel Areas in periods 5,6 and 7. COWRIE Ltd., United Kingdom.

Hille Ris Lambers, R., R. ter Hofstede. 2009. Refugium Effects of the MEP-NSW Windpark on Fish: Progress Report 2007. Institute for Marine Resources and Ecosystem Studies (IMARES). 23 pp.

Horn, J. W., E. B. Arnett, and T. H. Kunz. 2008. Behavioral responses of bats to operating wind turbines. *Journal of Wildlife Management*, 72:123-132.

Hötker, H., K.-M. Thomsen and H. Jeromin. 2006. Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation. Michael-Otto-Institut im NABU, Bergenhusen. http://bergenhusen.nabu.de/bericht/englische%20 windkraftstudie.pdf

Hüppop, O, J. Dierschke, K.M. Exo, E. Frederich, and R. Hill. 2006. Bird migration studies and potential collision risk with offshore wind turbines. *Ibis*, 148: 90-109.

Inger, R., M.J. Attrill, S. Bearhop, A.C. Broderick, W.J. Grecian, D.J. Hodgson, C. Mills, E. Sheehan, S.C. Votier, M.J. Witt, and B.J. Godley. 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. *Journal of Applied Ecology*, 46: 1145-1153.

Jarvis, C.M. 2005. An evaluation of the wildlife impacts of offshore wind development relative to fossil fuel power production. M.S. Thesis, University of Delaware, Graduate College of Marine Studies.

Jarvis, S., J. Allen, N. Proctor, A. Crossfield, O. Dawes, A. Leighton, L. McNeill, and W. Musk. 2004. North Sea Wind Farms: NSW Lot 1 Benthic Fauna. Final Report. University of Hull. 91 pp.

JNCC, NE, & CCW (Joint Nature Conservation Commission, Natural England, and Countryside Council for Wales). 2010. The protection of marine European protected species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area. Joint Nature Conservation Commission, Natural England, and Countryside Council for Wales.

Johnson, J. B., J.E. Gates, and N.P. Zegre. 2010. Monitoring seasonal bat activity on a coastal barrier island in Maryland, USA. *Environmental Monitoring and Assessment*, 173:685-

689.

Jonkman, J., S. Butterfield, W. Musial, and G. Scott. 2009. Definition of a 5-MW reference wind turbine for offshore system development. National Renewable Energy Laboratory Tech. Report NREL/TP_500_38060. Golden, Colorado.

Kahlert, J., I.K. Petersen, A.D. Fox, M. Desholm, and I. Clausager. 2004. Investigations of birds during construction and operation of Nysted offshore wind farm at Rodsand. Annual status report 2003. NERI report. Kalo, Denmark: National Environmental Research Institute. 82pp.

Kahlert, J., M. Desholm, I. Clausager, and I.K. Petersen. 2000. Environmental impact assessment of an offshore wind park at Rodsand: Technical report on birds. NERI, Denmark.

Keevin, T.M. and G.L. Hempen. 1997. The environmental effects of underwater explosions with methods to mitigate impacts. U.S. Army Corps of Engineers, St. Louis, Mo., USA.

Kelly, T.A., T.E. West, and J.K. Davenport. 2009. Challenges and solutions of remote sensing at offshore wind energy developments. *Marine Pollution Bulletin*, 58: 1599-1604.

Kenney, R.D., and C.R. Shoop. In press. Aerial surveys for marine turtles. Pp. 264-271 *in*: R.W. McDiarmid, M.S. Foster, J.W. Gibbons, C. Guyer, and N. Chernoff (eds). *Sampling Reptile Diversity: Standard Methods for Inventory and Monitoring*. University of California Press, Berkeley, CA.

Kinney, J., and R.D. Flood. 2005. Seabed morphology off Southern Long Island: Studies of artificial reefs and implications for wind farms. Marine Sciences Research Center, Stony Brook University. 14 pp.

Klima, E.F., G.R. Gitschlag, and M.L. Renaud. 1988. Impacts of the explosive removal off offshore petroleum platforms on sea turtles and dolphins. *Marine Fisheries Review*, 50(3): 33-42.

Komdeur, J., J. Bertelsen, and G. Cracknell. 1992. Manual for aeroplane and ship survyes of waterfowl and seabirds. International Waterfowl and Wetlands Bureau (IWRB) Special Publication no. 19. Ronde, Denmark: National Environmental Research Institute.

Kostylev, V.E, and Hannah, C.G. 2007. Process-driven characterization and mapping of seabed habitats. In: Todd, B.J., Greene, H.G. (Eds.), *Mapping the seafloor for habitat characterization*: Geological Association of Canada. Geological Association of Canada, pp. 171-184.

Krägefsky, S. 2010. Project DEFI-av (StUKplus): Study of the effects of offshore wind farms on fish and megafauna. In: Environmental research results at *alpha ventus* - first results. Bundesamt für Seeschifffahrt und Hydrographie [BSH].

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales

(*Eubalaenaglacialis*). *Marine Mammal Science*, 6:278–291.

Kunz, T. H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R. Pl Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. *Journal of Wildlife Management*, 71:2449-2486.

Kwan, K. C. Ho, G. Mei, Y. Li, Z. Ren, R. Xu, Y. Zhang, D. Lao, M. Stevenson, V. Stanford, and C. Rochet. 2006. An Automated Acoustic System to Monitor and Classify Birds, EURASIP 2006: 1-19.

Langhamer, O., and D. Wilhelmsson. 2009. Colonization of fish and crabs of wave energy foundations and the effects of manufactured holes: A field experiment. *Marine Environmental Research*, 68:151–157.

Langton, R., I.M. Davies, and B.E. Scott. 2011. Seabird conservation and tidal stream and wave power generation: Information needs for predicting and managing potential impacts. *Marine Policy*, 35:623-630.

Larkin, R.P., W.R. Evans, and R.H. Diehl. 2002. Nocturnal flight call of Diskcissels and doppler radar echoes over south Texas in spring. *Journal of Field Ornithology*, 73:2-8.

Lefebvre, A., C.E.L. Thompson, K.J. Collins, and C.L. Amos. 2009. Use of a high-resolution profiling sonar and a towed video camera to map a *Zostera marina* bed, Solent, UK. *Estuarine, Coastal and Shelf Science*, 82: 323-334.

Leijon, M., H. Bernhoff, M. Berg and O. Ågren. 2003. Economical considerations of renewable electric energy production – especially development of wave energy. Renewable Energy 28: 1201–1209.

Leonhard, S., and J. Birklund. 2006. *Danish offshore wind: Key Environmental Issues*; Chapter 4: Infauna, epifauna and vegetation - Change in diversity and higher biomass. DONG Energy, Vattenfall, The Danish Energy Authority, and the Danish Forest and Nature Agency. pp 44-63.

Logerwell, E., and K. Rand. 2008. Beaufort Sea Marine Fish Monitoring 2008: Pilot Survey and Test of Hypotheses. Alaska Fisheries Science Center, NOAA, Seattle, WA.

Louzao, M., J. Becares, B. Rodriquez, K.D. Hyrenback, A. Ruiz, and J.M. Arcos. 2009. Combining vessel-based surveys and tracking data to identify key marine areas for seabirds. *Marine Ecology Progress Series*, 391:183-197.

Love, M., and A. York. 2005. A Comparison of the fish assemblages associated with an oil/gas pipeline and adjacent seafloor in the Santa Barbara Channel, Southern California Bight. *Bulletin of Marine Science*, 77 (1): 101-117.

Love, M.S., J. Caselle, L. Snook. 1999. Fish Assemblages on mussel mounds surrounding seven oil platforms in the Santa Barbara Channel and Santa Maria Basin. *Bulletin of*

Marine Science, 65 (2): 497-513

Love, M, J. Hyland, A. Ebeling, T. Herrlinger, A. Brooks, and E. Imamura. 1994. A pilot study of the distribution and abundances of rockfishes in relation to natural environmental factors and an offshore oil and gas production platform off the coast of Southern California. *Bulletin of Marine Science*, 53 (2-3): 1062-1085.

Maclean, I.M.D., H. Skov, M. M. Rehfisch, and W. Piper. 2006. Use of aerial surveys to detect bird displacement by offshore windfarms. COWRIE DIPS-03-2006, BTO Research Report No. 446, UK.

Maclean, I.M.D., L. J. Wright, D. A. Showler, and M. M. Rehfisch. 2009. A review of assessment methodologies for offshore wind farms. British Trust for Ornithology, COWRIE Ltd., United Kingdom.

Madsen, P. T., M. Wahlberg, J. Tougaard, K. Lucke, and P. Tyack. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series*, 309: 279-295.

Mann, R., J.M. Harding, M.J. Southworth, and J.A. Wesson. 2005. Northern quahog (hard clam) *Mercenaria mercenaria* abundance and habitat use in Chesapeake Bay. *Journal of Shellfish Research*, 24(2): 509-516.

Martec Limited. 2004. Effects of pipelines/gathering lines on snow crab and lobster. Martec Limited, CEF Consultants Ltd, DRDC Atlantic, St. Francis Xavier University, Calgary.

Meibner, K., and K. Sordyl. 2006. *Ecological research on offshore wind farms: International exchange of experiences*; Chapter 1: Literature review of offshore wind farms with regard to benthic communities and habitats. German Federal Agency for Nature Conservation. pp 1-46.

Mellor, M., and M. Maher. 2008. Full Scale Trial of High Definition Video Survey for Offshore Windfarm Sites. COWRIE Ltd., Whitehaven, England.

Mellor, M., T. Craig, D. Baillie, and P. Woolaghan. 2007. Trial High Definition Video Survey of Seabirds. COWRIE Ltd., Whitehaven, England.

Minerals Management Service (MMS). 2001. Development and Design of Biological and Physical Monitoring Protocols to Evaluate the Long-term Impacts of Offshore Dredging Operations on the Marine Environment. MMS International Activities and Marine Minerals Division. MMS 2001-089.

Minerals Management Service (MMS). 2008a. Cape Wind Energy Project: Final Environmental Impact Statement.

Minerals Management Service (MMS). 2008b. Long-Term Monitoring at the East and West Flower Garden Banks, 2004-2005 - Interim Report.

Minerals Management Service. 2008c. Framework for the avian and bat monitoring plan for the Cape Wind Proposed Offshore Wind Facility. Appendix N. MMS, Herdon, VA.

Mizrahi, D., R. Fogg, T. Margarian, V. Elia, and D. La Puma. 2010. Radar monitoring of bird and bat movement patterns on Block Island and its coastal waters. Draft Interim Report. RI Ocean SAMP.

MMS (Minerals Management Service). 2009. *Cape Wind Energy Project; Final Environmental Impact Statement*. MMS EIS-EA, OCS Publication No. 2008-40, U.S. Dept. of the Interior, Minerals Management Service, Herndon, VA.

Moein-Bartol, S. and J.A. Musick. 2003. Sensory biology of sea turtles. Pages 79-102 in P.L. Lutz, J.A. Musick, and J. Wyneken, eds. *The Biology of Sea Turtles, Volume II.* Boca Raton, Florida: CRC Press, Inc.

Murawski, S.A., S.E. Wigley, M.J. Fogarty, P.J. Rago, and D.G. Mountain. 2005. Effort distribution and catch patterns adjacent to temperate MPAs. *ICES Journal of Marine Science*, 62: 1150–1167.

Muxika, I., A. Borja, and J. Bald. 2007b. Using historical data, expert judgment and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. *Marine Pollution Bulletin*, 55: 16-29.

Muxika, I., L. Ibaibarriaga, J. Saiz, and A. Borja. 2007a. Minimal sampling requirements for a precise assessment of soft-bottom macrobenthic communities, using AMBI. *Journal of Experimental Marine Biology and Ecology*, 349: 323-333.

National Research Council (NRC). 2007. *Environmental impacts of wind-energy projects*. Washington, DC: The National Academies Press.

NMFS (National Marine Fisheries Service) 2003. Taking of marine mammals incidental to specified activities; Construction of the east span of the San Francisco-Oakland Bay Bridge; Notice of issuance of an incidental harassment authorization. *Federal Register* 68(220): 54595-64609.

NMFS (National Marine Fisheries Service) 2009a. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Letter of Authorization. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD.

NMFS (National Marine Fisheries Service) 2009d. Taking and importing marine mammals; U.S. Navy training in the Cherry Point Range Complex; Final Rule. *Federal Register* 74(113): 28370-28391.

NMFS (National Marine Fisheries Service) 2009e. Taking and importing marine mammals; U.S. Navy training in the Hawaii Range Complex; Final Rule. *Federal Register* 74(7):

1456-1491.

NMFS (National Marine Fisheries Service) 2009f. Taking and importing marine mammals; U.S. Navy training in the Jacksonville Range Complex; Final Rule. *Federal Register* 74(113): 28349-28370.

NMFS (National Marine Fisheries Service) 2009g. Taking and importing marine mammals; U.S. Navy training in the Southern California Range Complex; Final Rule. *Federal Register* 74(12): 3883-3918.

NMFS (National Marine Fisheries Service) 2009h. Taking and importing marine mammals; U.S. Navy training in the Virginia Capes Range Complex; Final Rule. *Federal Register* 74(113): 28328-28349.

NMFS (National Marine Fisheries Service) 2009i. Taking and importing marine mammals; U.S. Navy's Atlantic Fleet Active Sonar Training (AFAST); Final Rule. *Federal Register* 74(16): 4844-4885.

NMFS (National Marine Fisheries Service) 2010b. Takes of marine mammals incidental to specified activities; Manette Bridge replacement in Bremerton, Washington; Notice; issuance of an incidental harassment authorization. *Federal Register* 75(128): 38783-38791.

NMFS (National Marine Fisheries Service) 2010c. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to open water marine seismic survey in the Chukchi Sea, Alaska; Notice; issuance of an incidental harassment authorization. *Federal Register* 75(156): 49760-49811.

NMFS (National Marine Fisheries Service) 2010d. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to operation and maintenance of a liquefied natural gas facility off Massachusetts; Notice; issuance of an incidental harassment authorization. *Federal Register* 75(136): 41440-41449.

NMFS (National Marine Fisheries Service) 2010e. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to operations of a liquefied natural gas port facility in Massachusetts Bay; Notice of issuance of an incidental harassment authorization. *Federal Register* 75(169): 53672-53678.

NMFS (National Marine Fisheries Service) 2010f. Taking and importing marine mammals; Military training activities and research, development, testing and evaluation conducted within the Marianas Islands Range Complex (MIRC); Final Rule. *Federal Register* 75(148): 45527-458556.

NMFS (National Marine Fisheries Service) 2010g. Taking and importing marine mammals; Navy training activities conducted within the Northwest Training Range Comples (NWTRC) and military training activities and research, development, testing and evaluation conducted witht the Mariana Island Range Complex (MIRC); Notice;

issuance three letters of authorization. *Federal Register* 75(243): 79342-79344.

NMFS (National Marine Fisheries Service) 2010h. Taking and importing marine mammals; Navy training activities conducted within the Northwest Training Range Complex; Final Rule. *Federal Register* 75(217): 69296-69326.

NMFS (National Marine Fisheries Service) 2010i. Taking and importing marine mammals; Taking marine mammals incidental to Navy operations of Surveillance Towed Array Sensor System Low Frequency Active Sonar; Notice; issuance of three Letters of Authorization. *Federal Register* 75(161): 51443-51444.

NMFS (National Marine Fisheries Service) 2010j. Taking and importing marine mammals; Taking marine mammals incidental to Navy training exercises in there East Coast Range Complexes; Notice; issuance of three letters of authorization. *Federal Register* 75(116): 34428-34429.

NMFS (National Marine Fisheries Service) 2010l. Taking and importing marine mammals; U.S. Navy training in the Hawaii Range Complex; Notice of issuance of a letter of authorization. *Federal Register* 75(16): 4049-4051.

NMFS (National Marine Fisheries Service) 2010m. Taking and importing marine mammals; U.S. Navy training in the Southern California Range Complex; Notice of issuance of a letter of authorization. *Federal Register* 75(16): 4047-4049.

NMFS (National Marine Fisheries Service) 2010n. Taking and importing marine mammals; U.S. Navy's Atlantic Fleet Active Sonar Training; Notice of issuance of a letter of authorization. *Federal Register* 75(20): 5055-5056.

Noer, H., T.K. Christensen, I.B. Clausager, I.K. Petersen. 2000. Effects on birds of an offshore wind park at Horns Rev: Environmental impact assessment. NERI, Denmark

NRC (National Research Council). 1990. *Decline of the Sea Turtles: Causes and Prevention*. Washington, DC: National Academy Press.

NRC (National Research Council). 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. Washington, DC: National Academies Press.

NWCC 2004. Wind turbine interactions with birds and bats: a summary of research results and remaining questions. National Wind Coordinating Committee, Nov. 2004. Available at www.nationalwind.org.

NWP Offshore Limited. 2008. North Hoyle Offshore Wind Farm - Final Annual FEPA Monitoring Report and Five Year Monitoring Program Summary. Npower Renewables Limited, Berkrshire, UK.

O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, *Caretta caretta,* to low frequency sound. *Copeia,* 1990:564-567.

Ohman, M.C., P. Sigray, and H. Westerberg. 2007. Offshore Windmills and the Effects of Electromagnetic Fields on Fish. *Ambio*, 36(8):630-633.

Orpin, A., and V. Kostylev. 2006. Towards a statistically valid method of textural sea floor characterization of benthic habitats. *Marine Geology*, 225: 209-222.

OSPAR Commission. 2004. Problems and Benefits Associated With the Development of Offshore Wind-Farms. Publication 212/2004.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR Commission. 2006. Review of the Current State of Knowledge on the Environmental Impacts of the Location, Operation and Removal/Disposal of Offshore Wind-Farms; Status Report April 2006. Publication 278/2006.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR Commission. 2008. Assessment of the Environmental Impact of Offshore Wind-Farms. Publication 385/2008.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR Commission. 2009. Overview of the Impacts of Anthropogenic Underwater Sound in the Marine Environment. Publication 441/2009.OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

OSPAR 2002. Joint Assessment and Monitoring Programme (JAMP) guidelines on quality assurance for biological monitoring in the OSPAR area. Ref no. 2002-15, 38 pp.

Page, H.M., J.E. Dugan, C.S. Culver, and J.C. Hoesterey. 2006. Exotic invertebrate species on offshore oil platforms. *Marine Ecology Progress Series*, 325: 101-107.

Palsson, W.A., T-S. Tsou, G.G. Bargmann, R.M. Buckley, J.E. West, M.L. Mills, Y.W. Cheng, and R.E. Pacunski. 2009. The Biology and Assessment of Rockfishes in Puget Sound. Washington Department of Fish and Wildlife: Fish Program.

Pandey. A., J. Hermence, and R. Harness. 2007. Development of a cost-effective system to monitor wind turbines for bird and bat collisions. Phase 1: sensor system feasibility study. California Energy Commission, CEC-t00-2007-004.

Paton, P., K.J. Winiarski, C.L. Trocki and S.R. McWilliams. 2010. Spatial distribution, abundance and flight ecology of birds in nearshore and offshore waters of Rhode Island. Draft Interim Report. RI Ocean SAMP.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torresh Jr. 1998. Fishing down marine food webs. *Science*, 279: 860–863.

PCAD Working Group. 2010. Introduction and progress of a working group on the population consequences of acoustic disturbance. IWC Scientific Committee meeting document

SC/62/WW5. International Whaling Commission, Cambridge, UK.

Peabody, M.B., and C.A. Wilson. 2006. Fidelity of Red Snapper (Lutjanus campechanus) to Petroleum Platforms and Artificial Reefs in the Northern Gulf of Mexico. Minerals Management Service.

Pearson, T.H., and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology: An Annual Review*, 16: 229-311.

Pelc, R. and R. M. Fujita. 2002. Renewable energy from the ocean. *Marine Policy*, 26:471-479.

Percival, S.M. 2001. Assessment of the effects of offshore wind in birds. DTA/Pub URN 01/1434. UK.

Percival, S.M. 2003. Birds and wind farms in Ireland: a review of potential issues and impact assessment. Unpubl. report. UK. 25 pp.

Perkins, S., G. Sadoti, T. Allison, and A. Jones. 2004. Relative waterfowl abundance within Nantucket Sound, Massachusetts during the 2003-2004 winter season. Unpublished report, Massachusetts Audubon Society. Lincoln, Massachusetts.

Perrow, M.R., E.R. Skeate, P. Lines, D. Brown, and M.L. Tomlinson. 2006. Radio telemetry as a tool for impact assessment of wind farms: the case of little terns Sterna albifrons at Scroby Sands, Norfolk, UK. *Ibis*, 148:57-75.

Petersen, I.K. 2005. Bird numbers and distributions in the Horns Rev offshore wind farm area. National Environmental Research Institute Report, Denmark.

Petersen, I.K., C.K. Christensen, J. Kahlert, M. Desholm, and A.D Fox. 2006. Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark. NERI Report, commissioned by DONG Energy and Vattenfall A/S, DK 166.

Pettersson, J. 2005. The Impact of offshore wind farms on bird life in southern Kalmar Sound, Sweden. Lunds University, Sweden.

Pilling, G.M., J. van der Kooij, G.M. Daskalov, A.J.R. Cotter, and J.D. Metcalfe. 2007. Overview of current best world practice in fish stock assessment and management, with specific reference to Caspian Sea fisheries. Sci. Ser. Tech. Rep., Cefas Lowestoft, 141: 158 pp

Polagye, B., B. Van Cleve, A. Copping, and K. Kirkendall. 2010. *Environmental Effects of Tidal Energy Development*. Proceedings of a Scientific Workshop. University of Washington, Seattle. March 22-25, 2010. NOAA Technical Memorandum NMFS F/SPO-116. 186 pp.

Polish Wind Energy Association. 2008. Guidelines for assessment of wind farms' impact on birds. Szczecin. 26 http://www.fws.gov/windenergy/docs/

Examples_State_International_Guidance_Duration_Intensity_Pre.pdf

Pollock, C.M., R. Mavor, C.R. Weir, A. Reid, R.W. White, M.L. Tasker, A. Webb, and J.B. Reid. 2000. The distribution of seabirds and marine mammals in the Atlantic frontier, north and west of Scotland. Joint Nature Conservation Committee

Popper, A.N., and M.C. Hastings. 2009. The effects of anthropogenic sources of sound on fishes. *Journal of Fish Biology,* 75: 455-489.

Powers, K. 1983. Pelagic distributions of marine birds off the northeastern United States. NOAA Technical Memorandum

Prior, A., and M.J. McMath. 2008. Marine mammals and noise from offshore renewables projects -- UK developments. Pp. 12-16 in: P.G.H. Evans (ed.). Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts. ECS Special Publication Series No. 49, European Cetacean Society,

Proctor, N., Jarvis, S., Allen, J., 2003. North Sea Windfarms; Lot 1 Benthic Fauna. Phase 1. Strategy of Approach. University of Hull. 20 pp.

Quintino, V., M. Elliott, and A. Rodrigues. 2006. The derivation, performance and role of univariate and multivariate indicators of benthic change: Case studies at differing spatial scales. *Journal of Experimental Marine Biology and Ecology*, 330: 368-382.

Rademacher, K.R. and J.H. Render. 2003. Fish assemblages around oil and gas platforms in the Northeastern Gulf of Mexico: Developing a survey design. In: *Fisheries, Reefs, and Offshore Development*. Stanley, D.R. and Scarborough-Bull, A., eds. American Fisheries Society Symposium 36. Bethesda, Maryland: American Fisheries Society.

Redfern, J.V., M.C. Ferguson, E.A. Becker, K.D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M.F. Baumgartner, K.A. Forney, L.T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A.J. Pershing, S.S. Qian, A. Read, S.B. Reilly, L. Torres, and F. Werner. 2006. Techniques for cetacean-habitat modeling: a review. *Marine Ecology Progress Series,* 310: 271-295.

Reedsport OPT Wave Park, LLC. 2010. Reedsport OPT Wave Park Joint Explanatory Statement for the Settlement Agreement Regarding the Construction and Operation of the Reedsport OPT Wave Park, FERC No. 12713, Douglas County Oregon. Available online at: http://elibrary.ferc.gov/idmws/File_list.asp?document_id=13836497.

Rees, H.L., J.L. Hyland, K. Hylland, C.S.L. Mercer Clarke, J.C. Roff, and S. Ware. 2008. Environmental indicators: utility in meeting regulatory needs. An overview. *ICES Journal of Marine Science*, 65: 1381-1386.

Reubens, J., S. Degraer, and M. Vincx. 2010 The importance of marine wind farms, as artificial hard substrata, for the ecology of the ichthyofauna. In: Degraer, S., Brabant, R. & Rumes, B. (Eds.) 2010. *Offshore wind farms in the Belgian part of the North Sea: Early* *environmental impact assessment and spatio-temporal variability.* Royal Belgian

Rhoads, D.C., P.L. McCall, and J.Y. Yingst. 1978. Disturbance and production on the estuarine seafloor. *American Scientist*, 66: 577-586.

Rice, J., C. Arvanitidis, A. Borja, C. Frid, J. Hiddink, J. Krause, P. Lorance, A. Ragnarsson, M. Sköld, and B. Trabucco. 2010. Marine Strategy Framework: Task Group 6 Report: Seafloor Integrity. European Commission Joint Research Centre. 81 pp.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. *Proceedings of the National Academy of Sciences*, 64:884-890.

Ross, B.P., J. Lien, and R.W. Furness. 2001. Use of underwater playback to reduce the impact of eiders on mussel farms. *ICES Journal of Marine Science*, 58:517–524.

RPS Planning and Development. 2008. Gunfleet Sands Offshore Wind Farm Development. DONG Energy, Copenhagen, Denmark.

Rye, J. H., A. Gilles, and U. Verfuß. 2008. Linking wind farms and harbor porpoises: review of methods. Pp. 21-26 in: P.G.H. Evans (ed.). *Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts*. ECS Special Publication Series No. 49, European Cetacean Society,

Samhouri, J.F., P.S. Levin, C. Andrew James, J. Kershner, and G. Williams. 2011. Using existing scientific capacity to set targets for ecosystem-based management: A Puget Sound case study. *Marine Policy*, 35: 508-518.

Scheidat, M., J. Tougaard, S. Brasseur, J. Carstensen, T. van Polanen Petel, J. Teilmann, and P. Reijnders. 2011. Harbor porpoises (*Phocoena phocoena*) and wind farms: a case study in the Dutch North Sea. *Environmental Research Letters*, 6: 10 pp.

Schroeder, B.A., and N.B. Thompson. 1987. Distribution of the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: results of aerial surveys. Pp. 45-53 *in:* W. N. Witzell, (ed.), *Ecology of East Florida Sea Turtles. Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop, Miami, Florida, February 26-27, 1985.* NOAA Technical Report NMFS 53. National Marine Fisheries Service, Miami, Florida.

Sheehan, E.V., T.F. Stevens, and M.J. Attrill. 2010. A quantitative, non-destructive methodology for habitat characterisation and benthic monitoring at offshore renewable energy developments. *PloS one* 5: e14461.

Shoop, C. R., and R. D. Kenney. 1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the northeastern United States. *Herpetological Monographs* 6:43-67.

Slotte, A., K. Hansen, J. Dalen, and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. *Fisheries Research, 67*: 143-150.

Snohomish County Public Utility District No. 1. 2009a. *Draft Environmental Report. Admiralty Inlet Pilot Tidal Project*. FERC Project No. 12690.

Snohomish Public Utility District (PUD). 2009b. Admiralty Inlet Pilot Tidal Project, Appendix B: Aquatic species and project operations monitoring plan. Snohomish County Public Utility District. 14 pp.

Snyder, B. and M.J. Kaiser. 2009. A comparison of offshore wind power development in Europe and the US: patterns and drivers of development. *Applied Ecology*, 86:1845-1856.

Stanley, D.R., and C.A. Wilson. 2003. Seasonal and spatial variation in the biomass and size frequency distribution of fish associated with oil and gas platforms in the Northern Gulf of Mexico. In: *Fisheries, Reefs, and Offshore Development*. Stanley, D.R. and Scarborough-Bull, A., eds. American Fisheries Society Symposium 36. Bethesda, Maryland: American Fisheries Society.

Stevenson, D., L. Chiarella, D. Stephan, R. Reid, K. Wilhelm, J. McCarthy, and M. Pentony. 2004. Characterization of the Fishing Practices and Marine Benthic Ecosystems of the Northeast U.S. Shelf, and an Evaluation of the Potential Effects of Fishing on Essential Fish Habitat. NOAA Technical Memorandum NMFS-NE-181.

Stokesbury, K.D.E. and B.P. Harris. 2006. Impact of limited short-term sea scallop fishery on epibenthic community of Georges Bank closed areas. *Marine Ecology Progress Series*, 307: 85-100.

Tasker, M., P.H. Jones, T. Dixon, and B.F. Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk*, 101: 567-577.

Tasker, M.L., P. Hope-Jones, B.F. Blake, T.J. Dixon, and A.W. Wallis. 1986. Seabirds associated with oil production platforms in the North Sea. *Ringing and Migration*, 7:7-14.

Taylor, B.L., M. Martinez, T. Gerrodette, J. Barlow, and Y.N. Hrovat. 2007. Lessons from monitoring trends in abundance of marine mammals. *Marine Mammal Science,* 23:157-175.

Taylor, C., 2001. Remote acoustic habitat assessment techniques used to characterize the quality and extent of oyster bottom in the Chesapeake Bay. *Marine Geodesy*, 24: 171-189.

Taylor, P.D., J.M. Brzustowksi, C. Matkovich, M.L. Peckford, and D. Wilson. 2010. radR: an open-source platform for acquiring and analyzing data on biological targets observed by surveillance radar. *BiomedCentral*, 10:22

Teilmann, J., J. Tougaard, and J. Carstensen. 2008. Effects from offshore wind farms on harbor porpoises in Denmark. Pp. 50-59 in: P.G.H. Evans (ed.). *Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts*. ECS Special Publication Series No. 49, European Cetacean Society,

Teilmann, J., J. Tougaard, and J. Carstensen.2006a. Summary on harbour porpoise monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Teilmann, J., J. Tougaard, J. Carstensen, R. Dietz, and S. Tougaard. 2006b. Summary on seal monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Thaxter, C.B. and N.H.K. Burton. 2009. High definition imagery for surveying seabirds and marine mammals: A review of recent trials and development protocols. COWRIE Ltd., Norfolk, United Kingdom.

Thompson, P. M., D. Lusseau, T. Barton, D. Simmons, J. Rusin, and H. Bailey. 2010. Assessing the responses of coastal cetaceans to the construction of offshore wind turbines. *Marine Pollution Bulletin*, 60:1200-1208.

Thomsen, F., K. Lüdemann, R. Kafemann, and W. Piper. 2006. Effects of offshore wind farm noise on marine mammals and fish, biola, Hamburg, Germany on behalf of COWRIE Ltd.

Thorne, R.E. 1994. Hydroacoustic remote sensing for artificial habitats. *Bulletin of Marine Science*, 55(3): 897-901.

Todd, B. J., & Kostylev, V. E. 2011. Surficial geology and benthic habitat of the German Bank seabed, Scotian Shelf, Canada. *Continental Shelf Research*, *31*(2), S54-S68.

Tougaard, J., and J. Carstensen. 2011. Porpoises North of Sprogø Before, During and After Construction of and Offshore Wind Farm. National Environmental Research Institute, Aarhus University, Aarhus, Denmark. 45 pp.

Tougaard, J., I. Ebbesen, S. Tougaard, T. Jensen, and J. Teilmann. 2003. Satellite tracking of harbour seals on Horns Reef; Use of the Horns Reef wind farm area and the North Sea. Biological Papers No. 3, Fisheries and Maritime Museum, Esbjerg, Denmark.

Tougaard, J., J. Carstensen, J. Teilmann, and N.I. Bech. 2005. Effects of the Nysted offshore wind farm on harbor porpoises. NERI Technical Report, Ministry of the Environment, Denmark.

Tougaard, J., O.D. Henriksen, and L.A. Miller. 2009b. Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbor porpoises and harbor seals. *Journal of the Acoustical Society of America*, 125:3766-3773.

U.S. Coast Guard. 2006. Neptune LNG Deepwater Port License Application: Final Environmental Impact Statement.

USFWS. 2011. Examples of state and international guidance for duration and intensity of pre-construction and post-construction monitoring. Accessed online at http://www.fws.gov/windenergy/docs/Examples_State_International_Guidance_Duration_Intensity_Pre.pdf

Van den Berg, G.P. 2004. Effects of the wind profile at night on wind turbine sound. *Journal of Sound and Vibration*, 227:955-970.

Van den Eynde, D., Brabant, R., Fettweis, M., Francken, F., Melotte, J., Sas, M., & Van Lancker, V. 2010. Monitoring of hydrodynamic and morphological changes at the C-Power and Belwind offshore windfarm sites – A synthesis. In: Degraer, S., Brabant, R., Rumes, B. (Eds.), 2010. *Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability.* Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. pp 19-36.

van der Wal, D., R.M. Forster, F. Rossi, H. Hummel, T. Ysebaert, F. Roose, and P.M.J. Herman. 2011. Ecological evaluation of an experimental beneficial use scheme for dredged sediment disposal in shallow tidal waters. *Marine Pollution Bulletin*, 62: 99-108.

van Hoey, G., A. Borja, S. Birchenough, L. Buhl-Mortensen, S. Degraer, D. Fleischer, F. Kerckhof, P. Magni, I. Muxika, H. Reiss, A. Schröder, M.L.Zettler, 2010. The use of benthic indicators in Europe: from the Water Framework Directive to the Marine Strategy Framework Directive. *Marine Pollution Bulletin*, 60: 2187-96.

Verdant Power. 2010. Roosevelt Island Tidal Energy Project, FERC No. 12611, Final Kinetic Hydropower Pilot Licence Application, Volume 4, Part 1: Proposed Monitoring Plans, RITE Monitoring of Environmental Effects (RMEE). Verdant Energy, LLC, New York, NY.D144+D167 http://www.theriteproject.com/uploads/VPRITE-FLAVol4-Part1of3.pdf

Verfaillie, E., S. Degraer, K. Schelfault, W.Willems, and V. Van Lancker. 2009. A protocol for classifying ecologically relevant marine zones, a statistical approach. *Estuarine, Coastal and Shelf Science*, 83: 175-185.

Verhoef, J.P., P.J. Eecen, R.J. Nijdam, H. Korterink, and H.H. Scholtens. 2004. WT-Bird: a Low Cost Solution for Detecting Bird Collisions. Petten, The Netherlands: ECN Wind Energy.

Von Oettingen, S. 2011. Bats and wind energy impacts. Presentation at conference, Orono, ME http://joomla.wildlife.org/Maine/images/WindEnergy/1_vonoettingen_2011%20tws%20 wind%20conf%20svo2.pdf

Wahlberg, M. and H. Westerberg. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. *Mar Ecol Prog Ser*, 288: 295-309.

Walker, R., L. Weiss, C.B. Frojan, D. Basteri, and R. Coggan. 2009. Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions, Benthic Ecology. Contract ME1117. CEFAS, Suffolk, UK. 19 pp.

Ware, S., S. G. Bolam, and H.L. 2010. Impact and recovery associated with the deposition of capital dredgings at UK disposal sites: lessons for future licensing and monitoring. *Marine Pollution Bulletin*, 60: 79-90.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2009.*U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2009*. NOAA Technical Memorandum NMFS-NE-213. National Marine Fisheries Service, Woods Hole, MA.

Westerberg, H.. I. Lagenfelt. 2008. Sub-sea Power Cables and the Migration Behaviour of the European Eel. *Fisheries Management and Ecology*, 15(5-6): 369-375.

Wiese, F.K., W.A. Montevecchi, G.K. Davoren, F. Huettmann, A.W. Diamond, and J. Link. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. *Marine Pollution Bulletin*, 42:1285-1290.

Wiley, D.N., J.C. Moller, and K.A. Zilinskas. 2003. The distribution and density of commercial fisheries and baleen whales within the Stellwagen Bank National Marine Sanctuary: July 2001-June 2002. *MTS Journal*, 37 (1): 35-53.

Wilhelmsson, D., T. Malm, R. Thompson, J. Tchou, G. Sarantakos, N. McCormick, S. Luitjens, M. Gullström, J.K. Patterson Edwards, O. Amir, and A. Dubi (eds). 2010. *Greening Blue Energy: Identifying and Managing the Biodiversity Risks and Opportunities of Offshore Renewable Energy*. International Union for the Conservation of Nature, Gland, Switzerland.

Wilhelmsson, D., T. Malm, and M. Ohman. 2006. The influence of offshore windpower on demersal fish. *ICES Journal of Marine Science*, 63: 775-78.

Wilhelmsson, D; Malm, T. 2008. Fouling assemblages on offshore wind power plants and adjacent substrata. *Estuarine, Coastal, and Shelf Science*, 79: 459-466.

Wilson, C.A. M.W. Miller, Y.C. Allen, K.M. Boswell, and D.L. Nieland. 2006. Effects of depth, location, and habitat type on relative abundance and species composition of fishes associated with petroleum platforms and Sonnier Bank in the Northern Gulf of Mexico. Minerals Management Service.

Wilson, J. C. 2007. Offshore Wind Farms: Their Impacts, and Potential Habitat Gains as Artificial Reefs, in Particular for Fish. M.S. thesis, University of Hull, Hull, UK.

Wiltschko, W. and R. Wiltschko. 2005. Magnetic orientation and magnetoreception in birds and other animals. *Journal of Comparative Physiology A – Neuroethology and Sensory Neural and Behavioral Physiology*, 191:675–693

Winiarski, K.J., Trocki, C.L., Paton, P., and McWilliams, S.R. 2011. Spatial distribution, abundance, and flight ecology of birds in nearshore and offshore waters of Rhode Island: January 2009 to August 2010. Final technical report for the Rhode Island Special Area Management Plan.

Winkelman, J.E. 1992. De involved van de Sep-proefwindcentrale te Oosterbierum (Fr.) opvogels. DLO-Instituut voor Bos- en Natuur-ornderzoek, RIN-rapport 92/2-5, 4 volumes, Arnhem.

Winkelman, J.E. 1992. The impact of the Sep wind park near Oosterbierum (Fr.), the Netherlands, on birds, 1: collision victims. RIN rapport 92/2. Arnhem IBN-DLO. (Dutch with English summary).

Zaugg, S., G. Saporta, E. van Loon, H. Schmaljohann., and R. Liechti. 2008. Automatic identification of bird targets with radar via patterns produced by wing flapping. *J.R. Soc. Interface,* 5(26): 1041-53.

Zrnic, D.S., A.V. Ryzhkov. 1998. Observations of insects and birds with a polarimetric radar. IEEE *Trans. Geosci. Rem Sens.*, 36 661-668.

Zydlewski, G., J. McCleave, H. Viehman, H. and K. Harmon. 2010. An initial assessment of fish presence and vertical distribution at two sites (control and proposed tidal power site) in Cobscook Bay. Ocean Renewable Power Company.

TASK 1.4

STANDARDIZED PROTOCOLS FOR ASSESSING THE EFFECTS OF OFFSHORE ALTERNATIVE ENERGY DEVELOPMENT ON CULTURAL RESOURCES

This report documents the work completed by the University of Rhode Island (URI) to develop standardized protocols for assessing the effects of offshore alternative energy development on cultural resources and centers around three content area tasks (tasks 1-3 below):

1. Proposing standards for geophysical survey in anticipation of offshore alternative energy development.
2. Proposing a conceptual framework for incorporating a Cultural Landscape Approach (CLA) to assessing and understanding cultural resources in areas that have been identified for potential offshore alternative energy development.
3. Proposing the use of Archaeological Sensitivity Analysis (ASA) to evaluate and assess cultural resources in potential offshore alternative energy lease blocks.

TASK 1.4

STANDARDIZED PROTOCOLS FOR ASSESSING THE EFFECTS OF OFFSHORE ALTERNATIVE ENERGY DEVELOPMENT ON CULTURAL RESOURCES

Contributing Authors:

P. August, URI Department of Natural Resources Science, Environmental Data Center
P.S. Pooler, National Park Service Inventory and Monitoring, Northeast Coastal and Barrier Network

EXECUTIVE SUMMARY

This report completes the Cultural Resource deliverables for the National Oceanographic Partnership Program (NOPP) Project Number: M10PS00152, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. The report documents the work completed by the University of Rhode Island (URI) to develop standardized protocols for assessing the effects of offshore alternative energy development on cultural resources and centers around three content area tasks (tasks 1-3 below):

1. Proposing standards for geophysical survey in anticipation of offshore alternative energy development.
2. Proposing a conceptual framework for incorporating a Cultural Landscape Approach (CLA) to assessing and understanding cultural resources in areas that have been identified for potential offshore alternative energy development.
3. Proposing the use of Archaeological Sensitivity Analysis (ASA) to evaluate and assess cultural resources in potential offshore alternative energy lease blocks.

For Task 1, the report outlines a two-tier approach to geophysical survey, instrumentation and survey resolution. Tier 1 corresponds to broad baseline surveys that are appropriate for evaluating the likely general effects of offshore alternative energy development in any particular area. For Tier 1 surveys, the report contains recommended strategies and instrumentation that are commensurate with these objectives. Tier 2 surveys are more detailed and correspond with archaeological surveys required by BOEMRE prior to development, disturbance and installation. For Tier 2 surveys, the report recommends slight modifications in current BOEMRE guidelines and standards for archaeological survey.

For Task 2, the report outlines a Cultural Landscape Approach (CLA) for identifying and evaluating the potential effects of ocean renewable energy siting on marine cultural heritage

resources. Pioneered and partially implemented in the Rhode Island Ocean Special Area Management Plan (SAMP), CLA advances the integrated management of cultural and environmental resources with the goal of improving the performance of NEPA and Section 106 reviews under the National Historic Preservation Act (NHPA) and to bring them into better alignment with the National Ocean Policy and its nine priority areas. The report recommends the adoption of new definitions and categories for cultural heritage resources developed under the auspices of the National Marine Protected Area Federal Advisory Committee in 2010. The basic theoretical underpinnings of CLA are described in this report and the example of Rhode Island's energy landscape is presented drawn from the Rhode Island Ocean SAMP. Basic CLA questions are provided as is a representative matrix for classifying historic shipwrecks for CLA analysis. While specific protocols for including tribal and indigenous cultural heritage are not provided here, the report strongly recommends the need for early and meaningful consultation with these groups as well as members of working maritime communities in developing landscape contexts and preservation priorities. CLA, the report states, offers a multidisciplinary and multicultural approach to cultural heritage that operates along the full spectrum of geographic scales, from the local to the global.

For Task 3, the report details three types of models and associated techniques that have the potential to contribute to assessing the effects of offshore alternative energy development on submerged cultural resources. These are Predictive Modeling, Paleo-Archaeological Landscape Reconstruction, and Archaeological Sensitivity Analysis (ASA). Each of these models and techniques is evaluated in terms of potential effectiveness and practicality. While statistical predictive models appear to be prohibitively time consuming and expensive, irrespective of whether they are designed for prehistoric or historic sites, both preliminary Paleo-Archaeological Landscape Reconstruction and Archaeological Sensitivity Analysis (ASA) hold considerable potential. Using the Rhode Island Ocean SAMP as a case study, the report looks at ways to enhance ASA for historic site, particularly shipwreck locations, using readily available data and linear regression. While the patterns of shipwreck loss revealed by the analysis of Rhode Island data may not be applicable in every location, the methodology for revealing those patterns is likely to be broadly pertinent.

STANDARDIZED PROTOCOLS FOR ASSESSING THE EFFECTS OF OFFSHORE ALTERNATIVE ENERGY DEVELOPMENT ON CULTURAL RESOURCES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This project, to develop standardized protocols for assessing the effects of offshore alternative energy development on cultural resources, centered around three content area tasks (tasks 1-3 below):

1. Proposing standards for geophysical survey in anticipation of offshore alternative energy development.
2. Proposing a conceptual framework for incorporating a Cultural Landscape Approach (CLA) to assessing and understanding cultural resources in areas that have been identified for potential offshore alternative energy development.
3. Proposing the use of Archaeological Sensitivity Analysis (ASA) to evaluate and assess cultural resources in potential offshore alternative energy lease blocks.

1.1. CONSULTATIONS AND THE PROJECT ADVISORY COMMITTEE

Researchers consulted with archaeologists and cultural resources from government, academia and private industry and in particular managers from BOEMRE and NOAA. This included but was not limited to a series of meetings at the Society for Historical Archaeology conference in Austin, Texas at the beginning of January, 2011 and also a presentation to the Project Advisory Committee (PAC) on June 1, 2011.

2. TASK 1 - STANDARDS FOR GEOPHYSICAL SURVEY

Archaeological survey has a substantial theoretical tradition and a substantial literature (see for example, Banning 2002). The scale and scope of archaeological survey is always dependent on the purposes and objectives of the work. Where the purpose is to gain a broad understanding of the number and types of sites in an area, survey strategy, instrumentation and lane spacing reflect those purposes. Alternatively, where the objective is to locate all significant cultural material in an area, the structure of the survey is different and reflective of those needs. BOEMRE, like its predecessor the Minerals Management Service, more frequently deals with the latter type of survey and has long-established guidelines for that work. (Minerals Management Service, 1999a; 1999b; 2005a; 2005b; 2005c; 2006; 2008; Bureau of Ocean Energy Management, Regulation & Enforcement, nd.) Nevertheless, broad reconnaissance-type archaeological surveys are more appropriate for baseline studies in anticipation of offshore alternative energy development. We recommend, therefore, a two-phase approach (or "two-tier" in current URI-NOPP project nomenclature). "Phase or Tier 1" would be archaeological surveys as part of broad baseline studies. "Phase or Tier 2" would be archaeological surveys of Areas of Potential Effect (APE) from offshore development (APE is the term used by BOEMRE and is common in cultural resource management). Tier 2 surveys are, in essence, similar to those already required by BOEMRE. Certainly, standards and instrumentation for these two tiers of survey could and should work in tandem, but in both conceptual and practical terms they would have to be separated to some degree.

2.1. TIER 1

We propose that Phase or Tier 1 studies dovetail with more intensive Phase or Tier 2 studies, but that the structure, instrumentation, and perhaps survey lane spacing be somewhat different. In the first instance, most alternative energy projects establish general areas for development, rather than specific locations for wind, wave or hydrokinetic energy installations. It is for this reason that broad, reconnaissance-level studies are recommended. Reconnaissance-level survey will not mitigate the needs for detailed cultural resource assessments should an Environmental Impact Statement be required (i.e. Tier 2 surveys), but it will establish good baseline data about potential sites and areas of archaeological sensitivity. This in turn will help inform both Cultural Landscape and Archaeological Sensitivity Analysis.

2.1.1. Tier 1 Studies and the Selection of Survey Areas

The size of the survey area, archaeological survey theory, and the range of likely archaeological resources should help govern the kinds of studies undertaken and the selection of survey areas for Tier 1 studies. To the extent possible, Tier 1 studies should take account of results of Archaeological Sensitivity Analysis (see ASA below); Cultural Landscape Approach or studies (see CLA below); the requirements for habitat and geotechnical studies; and National Register of Historic Places criteria for significance of historic resources.

Survey Strategies should be selected on a case-by-case basis but could include:

- Random or stratified sample based on blocks, grids units or transects
- Total survey of select areas
- Total survey of entire study area

In most cases, irrespective of whether the survey instrumentation is side scan sonar or a multibeam bathymetry system, it will be impractical to complete an acoustic geophyiscal survey of the entire study area. Survey areas, therefore, should be divided into survey blocks or transects and a stratified sample taken. In addition, areas deemed likely, through historic and archaeological research, to contain important, known, historic properties should be surveyed. These small scale, targeted surveys would augment the statistical sample. In all cases, surveyors should achieve 100% acoustic geophysical coverage of sampled survey blocks.

It is essential that work for Tier 1, broad-based, reconnaissance-level, archaeological survey should dovetail with geophysical surveys for benthic habitat analysis and geological studies. This ensures more effective use of funds and enhances synergy among scientists working in different disciplines.

2.1.2. Tier 1 Geophysical Survey Instrumentation

Recommended standards for Tier 1 geophysical survey should complement and to some extent parallel standards established by BOEMRE for more detailed archaeological work. Baseline studies should include, at a minimum, a dual-channel, dual frequency side scan sonar and a high resolution multibeam bathymetry system with sufficient resolution to see objects 0.5 m in length. Alternatively, side scan data and multibeam bathymetry could be achieved through the use of an interferometric sonar. Whether the archaeologists use side scan and multibeam or interferometric sonar, they should ensure that the survey is controlled using a state-of-the-art, survey-grade GPS navigation system and hydrographic software such as HYPACK. The nadir in side scan sonar surveys should be kept to a minimum.

Geophysical survey should also include the collection of sub-bottom profile data, which should be collected at high frequency. This will provide essential near-surface geology data, which in turn will help establish the extent of marine sediment deposition and possible relic surfaces. Although acoustic data should be the basis for reconnaissance-level geophysical surveys for cultural resources, marine magnetometer data is also useful. Once specific areas of potential effect (APE) have been established, marine magnetometer data becomes critical for assessing potential impacts of alternative energy projects on cultural resources (i.e. in Tier 2 surveys). It makes sense, therefore, to collect as much of this data as possible at the reconnaissance level bearing in mind, of course, the budgetary constraints of the project.

During post-processing, acoustic and magnetic features (or targets) and anomalies from the geophysical survey should be identified, listed and prioritized. A system should be developed that has at least a three, and preferably five, levels of potential significance, ranging from features that are certainly cultural resources to those that might conceivably be so. A qualified archaeologist, trained in geophysical survey, should identify and prioritize targets. Raw and processed geophysical survey data should be archived and cataloged.

As part of a Tier 1 baseline study, a representative sample of these features identified in the survey should be visually inspected, either by scuba-equipped archaeologists or remote operated vehicle (ROV). The archaeologists should prioritize these groundtruthing studies in accordance with the overall parameters of the project. In all cases where visibility permits, a photographic and video record should be acquired, archived and cataloged. Archaeologists should determine the source and identity of each groundtruthed target or feature. In cases where the feature is determined to be potentially (or actually) a historic or prehistoric site the archaeologist should assess the extent and stability of the site, and if possible, establish its date, form and cultural origin. No artifacts should be recovered, except in exceptional circumstances and in consultation with the requisite state or federal authorities. Archaeological sites that are unstable due to natural or human impacts should be monitored. Regular visual inspection and/or site stability studies should be undertaken. In certain cases, a detailed oceanographic characterization of the immersed environment might be necessary.

2.2. TIER 2

We propose that Phase or Tier 2 studies parallel current and proposed BOEMRE standards for full-scale archaeological survey, with one principal exception. We recommend that the agency restructure its acoustic mapping studies so as to incorporate multibeam technology more fully. Currently, BOEMRE requires side scan sonar survey, single beam echo sounder surveys and encourages multibeam surveys. (Bureau of Ocean Energy Management, Regulation & Enforcement, nd.) We propose that the agency require either side scan sonar and multibeam bathymetry surveys or interferometric sonar surveys.

Irrespective of any particular lease block's location, it will remain the prerogative of cultural resource managers at BOEMRE to require full-scale archaeological survey of APE (i.e. Tier 2 survey), and in many cases to recommend to the contractor that it undertake full archaeological survey of entire lease blocks. The agency has well established, but continuously evolving, standards for this kind of archaeological survey and subsequent reporting. These standards have undergone a number of iterations as new technology has become available. The standards are divided by region, but all contain sections on determining the APE, layout of the survey, navigation and control, bathymetry, magnetometer, side scan sonar, and sub-bottom profiler. The standards also contain sections on data collection and processing, reporting of archaeological sites, and protection of data and sites. The most recent versions of the standards address and require coordination with similar surveys for habitat and geotechnical studies. (Minerals Management Service, 1999a; 1999b; 2005a; 2005b; 2005c; 2006; 2008; Bureau of Ocean Energy Management, Regulation & Enforcement, nd.)

2.2.1. Analysis of BOEMRE Survey Requirements

BOEMRE archaeological survey standards state that the scope of investigation should be sufficient to reliably cover any portion of the site that will be affected by the renewable energy project including the maximum Area of Potential Effect (APE) encompassing all seafloor/bottom-disturbing activities. The maximum APE includes but is not limited to the footprint of all seafloor/bottom-disturbing activities (including the areas in which installation vessels, barge anchorages, and/or appurtenances may be placed) associated with construction, installation, inspection, maintenance, removal of structures and/or transmission cables. (Bureau of Ocean Energy Management, Regulation & Enforcement, nd.)

In general, BOEMRE requirements for cultural resource surveys can be divided into the following sections (summarized from BOEMRE and MMS standards):

Pre-Survey Meeting and Coordination

This meeting should discuss:

- Survey logistics (proposed survey area, dates, times, weather limitations, etc.)
- Vessel characteristics (size, equipment, etc.)
- Sea floor characteristics expected based on available information (depth, slope, substrate, etc.)
- Survey plan and equipment to be utilized
- Data processing and analysis
- Formulation of a quality assurance/quality control (QA/QC) protocol for data collection and interpretation

Survey Layout

The following should be applied to the layout of the archaeological survey:

- Oriented with respect to the bathymetry, shallow geologic structure, and renewable energy structure locations whenever possible.
- The grid pattern for each survey should cover the maximum APE for all anticipated physical disturbances.
- Line spacing for all geophysical data for shallow hazards assessments (on side scan sonar/all sub-bottom profilers) should not exceed 150 meters throughout the APE.
- Line spacing for all geophysical data for archaeological resources assessments (on magnetometer, side scan sonar, chirp sub-bottom profiler) should not exceed 30 meters throughout the APE.
- Line spacing for bathymetric charting using multi-beam technique or side scan sonar mosaic construction should be suitable for the water depths encountered and provide both full-coverage of the seabed plus suitable overlap and resolution of small discrete targets of 0.5m - 1.0m in diameter.
- All track lines should run generally parallel to each other. Tie-lines running perpendicular to the track lines should not exceed a line spacing of 150 meters throughout the APE.
- The geophysical survey grid for proposed transmission cable route(s) should include a minimum 300 meter-wide corridor centered on the transmission cable location(s). Line spacing should be identical to that noted above.

Navigation

- Ensure that the precision of the navigation system is ± 1 meter. Continuously log position fixes digitally along the vessel track and annotate them on all records at intervals no greater than 100 meters.

Bathymetry/Depth Sounder

- Depth sounder system to record with a sweep appropriate to the range of water depths expected in the survey area.
- "BOEMRE encourages use of a multi-beam bathymetry system particularly in areas characterized by complex topography or fragile habitats."

Magnetometer

- Magnetometer sensor should be towed as near as possible to the seafloor and at an altitude of no greater than 6 meters above the seafloor.
- Magnetometer sensitivity to be 1 gamma or less and that the background noise level does not exceed a total of 3 gammas peak to peak.

Sea Floor Imagery/Side Scan Sonar

- Data to be corrected for slant range, lay-back and vessel speed. Use a digital dual-frequency side scan sonar system with preferred frequencies of 445 and 900 kHz and no less than 100 and 500 kHz.
- Record continuous planimetric images of the seafloor.
- Data to be mosaiced
- Provide 100 percent coverage of the APE.
- Sidescan sonar sensor towed above 10 to 20 percent of the swath width.
- Ensure that the line spacing and display range are appropriate for the water depth and that they detect seafloor objects and features 0.5m – 1m in diameter

Shallow & Medium (Seismic) Penetration Sub-bottom Profilers

- A high-resolution "chirp" sub-bottom profiler should be used to delineate near-surface geologic strata and features.
- The sub-bottom profiler system should be capable of achieving a vertical bed separation resolution of at least 0.3 meters in the uppermost 15 meters below the mud-line.
- Contractors must be cognizant that the National Marine Fisheries Service (NMFS) considers sound levels above 160 dB re 1 μPa to constitute Level B harassment under the Marine Mammal Protection Act. Sounds above 180 dB re 1 μPa are considered Level A harassment.

2.2.2. Summary of Current BOEMRE Survey Requirements and Recommendations

By way of summary, BOEMRE archaeological survey requirements call for the collection of magnetometer data (less than 1 gamma sensitivity); side scan sonar (dual frequency – 445 and 900 kHz preferred) providing 100% coverage at a resolution high enough to identify objects 0.5 – 1.0 m in diameter; single beam echo sounder; and high-resolution "chirp" sub-bottom profiler (resolution 0.3 m in uppermost 15 m).

As technological advances in geophysical survey materialize so it is possible to require higher resolution surveys or new instrumentation. BOEMRE specifically recognizes this and "encourages innovative survey and data processing technologies." We recommend slight modification to the current requirements for archaeological and geophysical survey - namely magnetometer (less than 0.5 gamma sensitivity); either side scan sonar and multibeam bathymetry surveys or interferometric sonar providing 100% coverage and resolving objects 0.5m in diameter and high-resolution "chirp" sub-bottom profiler (resolution 0.3 m in uppermost 15 m).

In terms of post processing of geophysical survey data, we recommend the following:

- Acoustic data mosaiced

- Side scan targets tabulated
- Magnetic anomalies tabulated
- Establish buffer zones (at least 150 m) around potential archaeological resources
- Include analysis of cores taken for geotechnical studies
- Identify paleosols and preserved landscapes, if possible.
- Mitigation negotiable

3. TASK 2 CULTURAL LANDSCAPE APPROACH

The traditional way of assessing the impacts of coastal and offshore projects on cultural heritage resources involves focusing on the location, significance, and vulnerability of individual—physical—archaeological sites. Typically in the United States, this research has involved developing lists of the best-known shipwrecks and their possible locations with a particular project area. Frequently these lists or inventories are conjectural, as historically mentioned wrecks may or may not have actually occurred in a project area, or the wreck may have been recovered through unknown salvage operations. Despite a narrow focus, historic shipwrecks, unlike many underwater cultural resources, have at least received some consideration in coastal development, offshore oil and gas, and electrical and communication projects. They represent, however, only one of many kinds of potentially significant maritime cultural heritage resources that might be adversely affected by the development of offshore renewable energy.

The discussion that follows provides the rationale and basic framework for a more holistic Cultural Landscape Approach (CLA) for assessing the effects of offshore alternative energy development on Cultural Resources. It builds directly on the research completed through the Rhode Island Ocean Special Area Management Plan (SAMP), the experience of the Cape Wind Project in Massachusetts, extensive work by the NOAA National Marine Protected Area Federal Advisory Committee's cultural heritage resources working group, and discussions at the Atlantic Wind Energy Workshop sponsored by the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) and held on July 12-14, 2011. The recommendations below respond to widespread calls for the better integration of human factors in marine resource management, and for research and management methods that are sensitive to and inclusive of tribal and indigenous people and working maritime communities (Douvre 2008; Pomeroy and Douvre 2008; Crowder and Norse 2008; St. Thomas and Hall-Arbor 2008; Elher 2008).

3.1. DEFINING CULTURAL HERITAGE

Historic shipwrecks have dominated the practice of marine cultural heritage resource management in the United States for several decades. The term, however, has broader definitions. For example, the UNESCO Convention on the Protection of Underwater Cultural Heritage (2001) includes "all traces of human existence having a cultural, historical, or archaeological character which have been partially or totally underwater, periodically or continuously, for at least 100 years." The Convention offers many examples of cultural heritage including sites, structures, buildings, human remains, vessels and their cargoes, including their archaeological context and objects "of a prehistoric character." The Convention excludes resources under 100 years in age and more recent industrial heritage resources such as pipelines or cables and anything "still in use on the seabed" (Forrest 2002; Smith and Couper 2003). In the United States, such categorical exclusions are not in play. The general cutoff date for historic properties under federal law is older than fifty years, and can be less than under certain circumstances. Experience with the Cape Wind Project demonstrated that intangible cultural heritage such as sacred places and view sheds are significant maritime cultural resources vulnerable to alternative offshore energy development. Definitions of cultural heritage and protocols for assessment should thus be comprehensive, resonate with a broad range of cultures and community stakeholders, and conform to the National Ocean Policy promulgated by President Obama on July 19, 2010 in Executive Order 13547.

In order to more effectively characterize cultural heritage resources for offshore alternative energy projects, we suggest embracing definitions approved by the NOAA National Marine Protected Area Federal Advisory Committee in October 2011. These definitions were developed by a 21-member cultural heritage resources working group that included representatives from federal agencies, archaeologists, resource managers, academics, industry stakeholders, and many tribal and indigenous groups from throughout the United States, including Alaska and Hawaii.

National MPA System Definitions:

Cultural Heritage. The legacy of physical evidence and intangible attributes of a group or society which is inherited and maintained in the present and bestowed for the benefit of future generations.

Marine Cultural Resources. Marine Cultural Resources, both tangible and intangible, include, but are not limited to stories, knowledge, people, places, structures, or objects that identify the nation's history or native people's lifeways and traditions, both ancestral and contemporary. The broad array of stories, knowledge, people, place, structures, objects, together with the associated environment, that contribute to the maintenance of cultural identity/or reveal the historic and contemporary human interactions with an ecosystem.

Although not carrying the force of law, these definitions augment existing regulation practices mandated by the National Historic Preservation Act of 1966 (NHPA) and the National Environmental Protection Act of 1969 (NEPA). They provide a bridge from the practice of treating cultural heritage resources exclusively as individual sites or relicts to one that recognizes the coasts and oceans as complex social spaces that possess diverse cultural meanings and many different types of resources. They embrace the premise that understanding cultural heritage offers important avenues for better understanding and managing the human dimensions of coastal and marine ecosystems. In that sense, these definitions are consistent with the first of the nine National Priority Objectives outlined in the President's 2010 National Ocean Policy, the adoption of ecosystem-based management "as a foundational principle for the comprehensive management of our ocean, our coasts, and the Great Lakes."

3.2. FEDERAL RESPONSIBILITY FOR COASTAL AND MARITIME CULTURAL HERITAGE

The federal government has a long history of protecting certain classes of natural and cultural heritage resources associated with the oceans and Great Lakes (Elia 2000).

3.2.1. The American Antiquities Act of 1906 (AA)

The Antiquities Act initiated the modern era of federal responsibility for conserving cultural heritage. The act prohibits the appropriation, destruction, excavation, or injury of "any historic or prehistoric ruin or monument, or any object of antiquity, situated on lands owned or controlled by the Government of the United States without the permission of the Secretary of the Department of the Government having jurisdiction over the lands on which said antiquities are situated." The act authorized the President of United States to establish national monuments in order to protect "historic landmarks, historic and prehistoric structures, and other objects of interest" (16 USC 431-433). From its earliest uses by Theodore Roosevelt, vast areas and countless natural and cultural resources have gained protection under the Antiquities Act as National Monuments. The Papahanaumokuakea Marine National Monument, for example, encompasses 140,000 square miles of the Pacific and is largest area yet designated under the act. The Antiquities Act is limited to federal lands and, in the marine environment, to areas and resources inside the United States 12-mile territorial sea boundary or within designated National Marine Sanctuaries (Zander and Varmer 1996).

3.2.2. The Archeological Protection Act of 1979 (ARPA)

ARPA expands Antiquities Act protections to "archaeological resources and sites which are on public lands and Indian lands." Violators of the Act may face felony charges and substantial penalties for illegal excavation, procurement or trade of archaeological artifacts from federal and Indian lands. ARPA requires permits for research mandates and requires that federal land managers create public education and outreach programs to promote the protection of archaeological resources (McManamon 2000).

3.2.3. The National Marine Sanctuaries Act of 1972 (NMSA)

NMSA enables NOAA to regulate activities, issue permits, and assess civil penalties for those illegally excavating or destroying cultural heritage resources within sanctuaries. Significantly, cultural heritage resources within national marine sanctuaries or marine national monuments are not required to meet the historic preservation criteria established under the National Historic Preservation Act of 1966 (NHPA). Within tightly defined geographical boundaries the NMSA supports the comprehensive and integrated management and protection of natural and cultural resources. The NMSA does not explicitly prohibit energy development, but such projects maybe subject to additional restrictions or permit requirements.

3.2.4. The Sunken Military Craft Act (SMCA)

SMCA protects sunken U.S. military craft in all national and international waters and military craft owned by foreign governments in U.S. waters up to 24 nautical miles from shore. The SMCA asserts ownership of all sunken military craft and prohibits the application of the common law of finds and the maritime law of salvage to military craft without permission from the federal government. Sunken military craft are common in particular areas along the Atlantic Coast and are an important concern in assessing cultural heritage resources offshore alternative energy siting. The pollution potential of modern military craft and merchant vessels sunk in wartime is significant and determining the presence of such vessels is highly important for protecting human and environmental health in siting.

3.2.5. The Abandoned Shipwreck Act of 1987 (ASA)

ASA protects the historic shipwrecks that exist in large numbers throughout the U.S. coastal and Great Lakes waters. The core intent of the ASA was to protect historic shipwrecks from damage or destruction by salvagers—principally "treasure hunters" seeking to find and remove artifacts of portable economic value. The ASA also promotes non-destructive multiple use of historic shipwrecks. Under the ASA, the U.S. asserted title to all abandon shipwrecks embedded on state submerged lands or in coralline formations owned by a state. ASA also applies to any wreck on submerged state lands and eligible for, or included on, the National Register of Historic Places (U.S.C. 2105). The ASA transferred the title to abandoned shipwrecks to the state or Indian tribes owning the submerged lands on which the specific wreck resides. Abandoned historic wrecks in U.S. territorial waters remain the property of the United States out to twelve miles.

3.2.6 The National Historic Preservation Act of 1966 (NHPA) 36 CFR 800

NHPA requires the meaningful consideration of the potential effects of federally assisted or permitted projects on properties included on, or eligible for inclusion on, the National Register of Historic Places. Meaningful consideration includes consultation with all concerned parties (King 2003). Sections 110 and 106 are especially important for ocean renewable energy siting assessments.

Section 110 requires that federal agencies develop a preservation program "for the identification, evaluation, and nomination to the National Register of Historic Places, and protection of historic properties." It also reiterates the requirement that agencies consult "with other Federal, State, and local agencies, Indian Tribes, Native Hawaiian organizations carrying out historic preservation planning activities, and with the private sector."[16 U.S.C. 470h-2(a)] It requires that agencies be proactive in identifying properties that may be eligible for the National Register in its undertakings.

Section 106 of NHPA states:

The head of any Federal agency having direct or indirect jurisdiction over a proposed Federal of federally assisted undertaking in any State and the head of any Federal department or independent agency having authority to license any undertaking shall, prior to the approval of the expenditure of any Federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register. The head of any such Federal agency shall afford the Advisory Council on Historic Preservation established under Title II of this Act a reasonable opportunity to comment with regard to such undertaking. [16 U.S.C. 470F—Advisory Council on Historic Preservation, comment on Federal Undertaking]

Section 106 of NHPA specifies a process for "taking into account" the effects of federal undertakings such as offshore alternative energy projects. NHPA does not mandate the preservation of any cultural heritage resource. This "taking into account" requirement was showcased in Secretary of the Interior Ken Salazar's recent decision to issue permits for the Cape Wind Project despite its potential adverse effects on an area of Nantucket Sound determined eligible for inclusion to the National Register of Historic Places. The Section 106 process in Cape Wind systematically identified and considered impacts on eligible resources but overruled the recommendations of the Advisory Council on Historic Preservation in approving the project and left a legacy of mistrust among the Wampanoag tribe whose national register eligible landscape will be damaged.

The broad reach of tribal and indigenous cultural heritage combined with the legacy of Cape Wind make this an essential issue in siting—one that can be addressed in part by adopting the Cultural Landscape Approach recommended below in evaluating the potential impacts of offshore alternative energy development. No approach, however, will succeed without a meaningful process of communication. Tribal and Indigenous cultural heritage consultation and interpretation is sufficiently complex as to require separate and fuller treatment by appropriate representatives of tribal and indigenous peoples. The CLA framework requires meaningful engagement and the recommended Paleo-Archaeological Landscape Reconstructions (see section 4.0 below) and models should serve the interests of Cultural and Indigenous Tribal Historic Preservation Offices (THPO).

Offshore alternative energy siting will require a Section 106 review. Agencies charged with completing a 106 review are required to coordinate with NEPA reviews, identify appropriate State and Tribal Historic Preservation officers, involve the public, and consult with a wide range of interested parties including Indian tribes or indigenous people, local governments, and stakeholders representing a wide variety of interests. An effective 106 process is transparent, broadly inclusive, proactive in consultation, and will integrate a wide range of interdisciplinary knowledge generated through processes such as NEPA. To often, however, the Section 106 process gets derailed through a lack of understanding and misinformation among agencies and interested parties. Conducting an archaeological survey does not, as some believe, constitute fulfillment of agency responsibilities under Section 106 (King 2008).

The National Register of Historic Places

The chief instrument of the NHPA is the National Register of Historic Places. Through appropriate research and the proper interpretation, National Register standards and guidelines may accommodate a broad array of place-based cultural heritage resources. An excellent example of this is the determination of eligibility for Nantucket Sound as a traditional cultural, historic and archaeological property issued by the Keeper of the Register on January 4, 2011. The National Register's overall history in maritime cultural heritage, however, is inconsistent. Standardized cultural heritage resource protocols through CLA should lead to improved use of the National Register and the Section 106 review process in offshore alternative energy siting.

Categories of Significance

The National Register includes properties (districts, sites, buildings, structures, or objects) determined significant in American history, architecture, archeology, engineering, and culture. Properties may be eligible for the National Register under one or more of four broad categories:

1. Association with events that have made a significant contribution to the broad patterns of our history.
2. Association with the lives of significant persons in the past.
3. Embodying the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction.
4. Have yielded or may be likely to yield, information important in history or prehistory.

Furthermore a property must be at least fifty years old, unless it has a unique and important place in recent American history.

Integrity

For inclusion on the National Register a historically significant property must also possess integrity of location, design, setting, materials, workmanship, feeling, and association. Integrity may be broadly understood as a properties capacity of a property to convey its historical significance. Significant underwater archaeological sites are often listed under Category D. Properties nominated under D generally do not necessarily require a high degree of visible site preservation to meet integrity requirements for inclusion on the National Register.

Improving National Register Consistency

NHPA authority is limited to cultural resources eligible for or included on the National Register of Historic Places. The Section 106 process of the NHPA is triggered by the presence or likely presence of potentially eligible, eligible or listed properties that may be affected by the proposed project. Although detailed standards and guidelines exist for many types of properties, determining National Register eligibility depends as much or more on subjective cultural or professional values and the level of research undertaken, as it does objective standards (King 2008).

Large inconsistencies exist among the states in managing marine cultural heritage resources. For example, according to the Rhode Island Historical Commission, the Ocean State has an estimated 2000 shipwrecks—yet only two appear on the National Register. By contrast Wisconsin, a state with between 600 and 700 historic shipwrecks, has over 30 on the National Register. The research of the Rhode Island Marine Archaeology Project (RIMAP) and more recently the University of Rhode Island for the Ocean SAMP leave no question that dozens of Rhode Island shipwrecks are eligible for inclusion on the National Register and subject to Section 106 review (Mather and Jensen 2010). The potential number of National Register eligible historic wrecks along the Atlantic Coast likely number in the thousands. While shipwrecks typify the challenges associated with maritime cultural heritage management, they extend to other cultural heritage resources, among them submerged structures, habitations, prehistoric landscapes, and sacred grounds.

The lack of consistency by states in applying the NHPA and National Register criteria to underwater cultural heritage properties has many sources. The historic preservation professional community has its foundations in historical architecture supplemented by degree history and terrestrial archaeology. Comparatively few historic preservation professionals have knowledge of the natural and cultural marine resources and environments, and most lack access to technologies and skills required for marine archaeological research. The high cost associated with marine archaeological field research, along with limited professional capacities in understaffed and underfunded offices, represents a heavy burden that many SHPO's choose or are forced to ignore. As a result, the majority underwater maritime cultural heritage resources in waters of most states remain undiscovered, unrecognized, or undervalued.

The fact that most ocean alternative energy siting will take place in federal waters is providing important opportunities to bring consistency and improved quality to maritime cultural heritage resource assessments. For example the Bureau of Ocean Energy Management and Research and Enforcement (BOEMRE) through the Secretary of Interior's "Smart from the Start" Atlantic OCS Offshore Wind Initiative, is taking steps to identify research priorities and best practices across many disciplines and issue areas. The Socio-Economic breakout session of the Atlantic Offshore Wind Energy Workshop organized by BOEMRE and held on July 13 and 14, 2011 identified five information area/research needs themes, two of these: "cultural landscapes" and "submerged ancient tribal sites" relate directly to the NHPA and applications of Section 106. The participants in these sessions reiterated the need to improve capacities to incorporate past and present cultural perspectives in assessing potential energy projects. The Cultural Landscape Approach is one response to that need.

NHPA Issues in Maritime Cultural Heritage Assessment

- The NHPA is only one of the sources of federal regulatory responsibility over coastal and marine cultural heritage resources.
- The NPHPA through Section 106 applies only to resources listed on or potentially eligible for the National Register of Historic Places.
- Decisions regarding eligibility of maritime cultural heritage resources depend in large part on highly subjective judgments and the level of research undertaking in assessing resources.
- Eligibility decisions and preservation priorities vary dramatically between the different states.
- Section 106 compliance requires more than identifying and assessing the National Register status of cultural heritage through archaeological survey.
- Section 106 mandates process and not preservation and requires early and transparent communication and consultation among interested parties.

- In order to meet their responsibilities under Section 106, agencies and developers should employ a comprehensive and consistent framework that takes into account the subjective as well as the objective factors associated with cultural heritage resources and that encourages appropriate transparency and genuine communication among all interested parties.

3.2.7. The National Environmental Protection Act of 1969 (NEPA)

The broadest federal law that applies to marine cultural heritage resources is the National Environmental Protection Act of 1969 (NEPA). NEPA has wide ranging authority for "managing the impacts of federal government actions on all aspects of the human environment." NEPA defines the human environment as "the natural and physical environment and the relationship of people with that environment" (King 2008). Section 101(b) of NEPA requires that the federal government "improve and coordinate federal plans, functions, programs and resources" in order to balance the use, maximum social benefits, and long term sustainability of the natural and human environments. Among its specific dictates is to "preserve important historic, cultural, and natural aspects of our national heritage, and maintain, whenever possible, an environment which supports diversity, and a variety of individual choice." Environmental and cultural factors are intertwined throughout NEPA and thus require integrated assessment is required when considering the effects of offshore alternative energy development on cultural heritage resources (Oxley 2001). To cite one example: the oil-filled wreck of a World War II T1 tanker may be at once a National Register eligible archaeological site, a memorial or grave site, a recreational and commercial resource, a site of locally significant habitat, and a looming environmental threat.

Our notions of how far the human environment extends to ocean spaces have expanded significantly since the passage of NEPA in 1969, as has our knowledge of the direct influences marine environments, resources, and systems (natural and cultural) on human communities. The influences are important, but often difficult to discern on the ocean, at a local scale, or over a short time period. Properly assessed tangible and intangible cultural heritage resources can make important human-environment connections visible in ways that can inform the collaborative and interdisciplinary decision-making and social values envisaged in NEPA and the NHPA.

3.2.8. Expanded Definitions for Significance in Maritime Cultural Heritage Resources

As originally approved, the Framework for NOAA's National System of Marine Protected Areas embraced National Register eligibility as the single standard for determining if an MPA qualified under its cultural heritage track. The cultural heritage resources working group established through the MPA Federal Advisory Committee (FAC), closely evaluated the framework and determined that while the National Register standards are important, they are, on their own, too limiting to serve as the exclusive definition for cultural heritage in MPAs. For example, these standards institutionalize a dependant status for federally recognized tribes that are required by law to be treated as independent nations and that have right to make their own designations, based on their own criteria. The National Register, the cultural heritage resources working group also held, provided no means of recognizing cultural heritage resources for their potential to provide important historical and contemporary biophysical information crucial for understanding historical and contemporary ecosystems. Embracing the working group's recommendations the MPA FAC voted to expand the MPA Framework's conception of a cultural heritage MPA:

Cultural Heritage MPAs must conform to the criteria included in the National Register of Historic Places, or be considered important by Indian Tribes, tribal communities, Alaska Natives, Native Hawaiians, or Pacific Islanders, or have the potential to provide information important to understanding cultural and natural heritage.

In addition to the National Register criteria previously described, cultural resources include the following for the purposes of inclusion into the national system of MPAs:

Tribal and Indigenous Area Designations.

As identified by oral or written record, indigenous stories, knowledge, people, places, structures, objects, and traditional practices contribute to maintaining cultural identity and/or sustainable management of the environment. The national system will include cultural and natural marine resources that are recognized as important by tribal or indigenous peoples. Some examples are, but not limited to:

1. Areas of cultural value or historic significance to tribes and indigenous peoples.
2. Traditional cultural properties, including areas of spiritual value.
3. Important Great Lakes and marine subsistence areas.
4. Important ceremonial sites and traditional activity sites.
5. Tribal usual and accustomed areas.
6. Other areas as determined important by tribal or indigenous peoples.

Other Cultural Landscapes

A place where the intersection of culture and nature leaves a distinct ecological or cultural imprint, and which is imbued with lasting meaning by a particular group through contact, experience, and activities.

3.3. The Cultural Landscape Approach (CLA)

The Cultural Landscape Approach (CLA) to maritime cultural heritage resources addresses contemporary management challenges by providing an open-ended and rigorous framework that integrates data and perspectives from the physical and social sciences, humanities, and traditional/place-based knowledge systems. CLA recognizes that places and cultural heritage resources can have different or multiple meanings and levels of significance based on how people from different cultures, times, or backgrounds have interacted with the landscape. Adopting this pluralistic approach increases the likelihood that cultural heritage resources will be found, recognized, and appropriately respected as decisions are made about the siting and potential effects of offshore alternative energy projects.

CLA offers fundamental principles about the nature of cultural heritage resources and suggests methods for identifying and characterizing interactions between human cultures and activities and coastal and marine environments. Cultural heritage resources, whether in the form of archaeological sites or living cultural practices, are records of these interactions over time. They reveal how people have used and shaped marine environments, and how these environments have shaped human cultural and history. Understanding these interactions may offer our best hope for sustainably and equitably using, maintaining, and where required restoring coastal and marine ecosystems (Crowder and Norse 2008; Douvre 2008).

3.3.1. CLA Fundamentals

The impulse for people to make sense of their relationships with nature is ancient. It is expressed in many place-based religious practices as well as in the knowledge systems of tribal and indigenous people found throughout the world. Modern western religious and scientific traditions have often served to separate in intellectual and moral senses humankind from the natural world.

In the 1920s, a rejection of geographical determinism inspired the founding of the field cultural geography in the United States, with the cultural landscape becoming one of its central concepts. Landscape architect Carl Sauer—the father of modern cultural geography—offered a definition of cultural landscape remains influential nearly a century after its articulation. Sauer explained, "the cultural landscape is fashioned from the natural landscape by a cultural group. Culture is the agent, the natural area is the medium, the cultural landscape is the result" (Wilson and Groth 2003). Since Sauer's early work the idea of the cultural landscape has been embraced and reshaped by many disciplines and has given rise to enormous and complicated academic literature. Scholars and regulatory bodies worldwide have developed different definitions for cultural landscapes as well as schema for indentifying and evaluating their meaning and significance. The idea of cultural landscapes is found in geography, landscape architecture, anthropology, landscape conservation, archaeology, as well as other disciplines (Westerdahl 1992; Angelstram 1997; Farina 2000).

However adapted, the foundations of cultural landscapes remain the interplay between nature and culture. In CLA, this interplay is dialectical. Cultures are highly influenced by the physical environment and the cultures consistently reshape the malleable (or valuable) aspects of that physical environment. CLA holds that both people and the environment are agents that shape the content of cultural landscapes.

Cultural heritage resources are comprised of things that exist in the natural/physical world and shaped through human actions or human thought - or a combination of both. For example, a brilliant sunrise brings morning light to a bluff on New England's south coast. This is a physical process found in nature. The cultural significance of this event is produced through long-practiced patterns of human behavior and belief. No human hand transformed the sunrise, but human thought and practices give it a deep cultural meaning recognized in Nantucket Sound's determination of eligibility for the National Register of Historic Places. Determining meaning is essential in assessing cultural heritage resources. To site a more contemporary heritage resource, the site of the World Trade Center towers destroyed in on September 11, 2001, retains few of the material remains of the buildings where nearly 3,000 people lost their lives in a terrorist attack. Even if every original element is removed for reasons of public health or to rebuild, the cultural meaning of the World Trade Center would remain fully intact for most Americans, and nearly all of those who live and work near Manhattan. Employing CLA requires researchers to search for and to recognize the evidence of human meaning found in sunrises, historic shipwrecks, submerged landscapes, fishing grounds, and or any other places where culture and nature come together to create substantial cultural markers.

Identified and mapped through interdisciplinary research, cultural landscapes offer a means to better understand where significant and vulnerable cultural heritage resources are more or less likely to survive. A deeper analysis of identified cultural landscapes will reveal what the contents of these landscapes mean to different cultures or groups of people. It will also help cultural resource professionals and all interested parties to collaborate in determining which resources found within the landscape, or parts of the landscape, are likely candidates for the National Register and the Section 106 process, or that merit special preservation or mitigation efforts under NEPA.

CLA places living and non-living resources with larger cultural contexts that are tied to the human uses of specific places. It identifies explicit ways that human history shaped and was shaped by important elements of the natural environment (living and non-living, natural and cultural) within a geographically defined area. CLA identifies material and intangible cultural markers found within a specified area, and assesses the patterns of human activity that underlie them across time. CLA makes visible the multiple and sometimes conflicting cultural meanings that may be associated with a specific geographic area and its resources. The approach is place-based, interdisciplinary, and adaptive. Emphasizing the potential importance of all human/ecosystem interactions, CLA is consistent with ecosystem-based approaches to management required by national policy (Arkema et al. 2006; Curtin and Prellezo 2010; Crowder and Norse 2008);.

CLA principal features:

- Place-based and operates at multiple geographic scales from the local to the global.
- Makes visible cultural and environmental processes that are most influencing the composition and meaning of cultural heritage resources within given area.
- Requires the identification, involvement, and open representation of the views of all cultures and historically rooted groups with ties to an area under study.
- Culturally contingent, cultural landscapes and cultural heritage resources are open to multiple even conflicting interpretations by different cultures or disciplines.
- Adaptive- new landscapes may be identified within areas, or new meanings developed based on additional data or fresh perspectives.
- Consistent with ecosystem-based approaches to management.
- Supports inclusiveness and transparency in decision-making.

CLA outcomes include:

- Identifying a representative range of cultural heritage resources that are potentially eligible for the National Register of Historic Places within a project area.
- Identifying, providing and representing the connections of tribal/indigenous cultural and historically rooted stakeholder groups in an area.
- Identifying important historical and cultural forces most influential in determining the composition of cultural resources and the condition of local ecosystems in area over time.
- Identifying the natural resources and environmental factors that have consistently influenced the human uses of an area over time.

3.3.2. CLA Implementation - the Rhode Island Ocean SAMP Experience

Between 2007-2010, the University of Rhode Island in collaboration with the Rhode Island Coastal Resources Management Council produced a Special Area Management Plan (SAMP) for Rhode Island offshore waters. The Ocean SAMP is an example of coastal and marine spatial planning that employed the best available science to understand the natural, physical and cultural environment in the study area. The Ocean SAMP included a study of cultural resources in Rhode Island's offshore waters. In addition to building the usual databases of known and potential cultural resources, the researchers developed and implemented limited CLA-based research and analysis study to produce a series of landscape contexts based on historical and cartographic research, geophysical and archaeological survey, and diver reconnaissance (Rhode Island Coastal Resources Management Council 2010)

URI researchers developed a series of core CLA questions for the Ocean SAMP that guided research and identified historical processes and historical actors that most significantly shaped the region's submerged historic cultural landscape. The CLA based questions aided in interpreting geospatial databases consisting of historical, archaeological, and geological information.

CLA Questions considered by researchers in the Ocean SAMP:

- What people have used this place?
- How have they used it?
- Over what time frame have these uses taken place?
- What are the principle human practices that have altered or sustained the natural environment of the place?
- What evidence of these activities exists or might exist in the physical landscape or in living cultures?
- How can the cultural heritage of this place be linked to the recovery, preservation and conveyance of human stories and knowledge?

- In what ways has this heritage contributed to or undermined the ecological and cultural resilience of this place?

Not all of these questions were explored in the same depth—fully addressing the linkages between cultural processes and contemporary environmental conditions fell outside of the cultural heritage team's scope of work for the Ocean SAMP. The potential for applying these questions in resource assessment, however, was amply demonstrated in the development of a series of landscape contexts the representing the historical uses of the Ocean SAMP survey area that produced the largest quantity of historical archaeological materials.

Three landscape contexts - fishing, military, and energy - explained the presence and potential meaning of the majority of likely and confirmed historical submerged cultural resources in the study area. While other contexts or broad areas of activity are represented in the archaeological record, these three areas emerged as the most important for the purposes of planning and assessment in Rhode Island Sound. While prehistoric and tribal cultural landscapes and heritage fell outside of the team's scope of work, the Ocean SAMP included of an unfiltered history based on oral traditions and memories produced by Narragansett tribe. The Narragansett history is a model for taking early steps defining a tribal landscape in a comprehensive CLA-based study.

The energy landscape

The identification of an energy landscape yielded the deepest new insights into the Ocean SAMP area's submerged maritime heritage. CLA revealed that the changing availability and demand for energy, including wood, peat, coal, petroleum oil, and wind have profoundly influenced the cultural heritage and natural environment of the Ocean SAMP area and the associated coastal zone. For understanding the formation of Rhode Island Sound's historical submerged historic shipwreck resources and principal maritime structures on land, the growing use and methods for transportation of coal are the most important. In the 19th century, industrialization reshaped Rhode Island's terrestrial cultural landscapes by creating factories, mills, working neighborhoods and industrial cities. Largely unrecognized is that industrialization also caused important alterations to the Rhode Island's coastal environment through the construction or improvement of harbors, dredging of shipping channels, and construction or improvements to lighthouses, docks, and lifesaving stations (Rhode Island Coastal Resources Management Council, Vol. I, Ch. 4. 2010)

Research revealed that the majority of historic shipwrecks in the Ocean SAMP area are tied to the transportation of coal to New England, principally from Virginia and New York. Most of these shipwrecks occurred between 1850 and 1918, a period when American consumption of coal grew 77-fold. Although Southern New England was at the heart of America's industrial revolution, the region lacked industrial quantities of native coal. As demand grew, the region looked to the sea to secure large, economical, and stable supplies. This demand for abundant, dependable, and inexpensive energy in New England led to an ad hoc system of transportation that relied on a motley and vulnerable armada sailing vessels, schooner barges and barges. During the peak decades, sometimes 200 vessels carrying coal passed by Block Island in Rhode Island Sound each day. Poorly paid mariners (men and women) from diverse racial and ethnic backgrounds that represented the lowest strata on the regional maritime social scale provide the labor for the ships, with many losing their lives. Within this context between 1870 and 1900, the frequency of shipwrecks increased dramatically in the Northeastern U.S. and as much as six-fold in the Ocean SAMP area, with high numbers of wrecks continuing until about 1920 when major changes in technology and supply routes reduced the risks associated with shipping coal. The energy landscape associated with coal transport to New England extends from Virginia to Maine and explains the presence of hundreds of shipwrecks along the Atlantic Coast. (Rhode Island Coastal Resources Management Council, Vol. I, Ch. 4. 2010)

The energy landscape did not begin with, nor does it end with, coal. Analysis of the energy landscape led to significant reassessments of the significance of known wrecks such as the iron tanker Llewellyn Howland that broke up on Seal Ledge near Aquidneck Island in 1924, dumping thousands of barrels of fuel oil into area waters. An early environmental disaster and well-known wreck event, the ship's historical significance as one of the first generation of purpose built oil tankers (built in 1888) remained unrecognized until viewed through the lens of energy. (Rhode Island Coastal Resources Management Council, Vol. I, Ch. 4. 2010)

In Southern New England, the continued use of the sea to transport low cost energy continues to result in significant accidents, including serious pollution events such as the oil spills associated with the grounding of the barge North Cape in Narragansett Bay, Rhode Island in 1996, and the rupturing of Bouchard Oil Barge 120 in Buzzards Bay, Massachusetts in 2003. The economic, geographic, and technological context of transporting energy to New England continues to influence the area's maritime cultural landscape, and the threat that it poses to the health of coastal and marine ecosystems in an age of petroleum. (Rhode Island Coastal Resources Management Council, Vol. I, Ch. 4. 2010).

In addition to identifying resources associated with the past, CLA also helps to reveal material evidence of linkages between important areas of human activity on land and at sea. Shipwreck patterns over time reveal the influence of specific economic forces, geographic features, and climate patterns on human activity in the marine places. The influence of these long-term factors is not always obvious, and most will continue to shape human activity as the country moves offshore for clean alternative energy. Applying a Cultural Landscape Approach not only identifies important historical and cultural heritage resources that may be adversely effected through development, it goes a step further by spotlighting cultural and natural forces that have the capacity to influence positively and negatively the success of offshore energy projects in specific areas.

The energy landscape identified in the Ocean SAMP underscores the limitations of relying on standard historic preservation-based approaches to cultural heritage resources in marine environments. Transporting energy has long been and remains an important activity in Rhode Island Sound. It has resulted in a cultural landscape rich with historic archaeological resources and, in some places, evidence of alterations to the environment. Before applying CLA the energy landscape shipwrecks were largely dismissed as having little or no archaeological and historical value for Rhode Island history. CLA demonstrated that coal shipping was a central facet of the growth of industry in Rhode Island, and provided a contextual framework that will useful for determining the historical significance and integrity of historic shipwrecks under Section 106 of the NHPA (Rhode Island Coastal Resources Management Council, Vol. I, Ch. 4. 2010).

3.3.3. Standardized Approaches to CLA

CLA is open-ended, culturally pluralistic, and adaptive. One its chief attributes is that it provides a way to capture the uniqueness of marine places. While proscribing a rigid model defeats this purpose, CLA can be implemented so as to achieve general consistency in use while preserving its capacity to capture the specific characteristics of different places. CLA works by the asking of specific types of questions, locating the appropriate types of evidence, and identifying meaningful landscape contexts to represent the major cultural patterns responsible for the material and intangible cultural resources within a specific study area. The questions, evidence, and contexts all contribute to a more culturally inclusive and interdisciplinary understanding of the human uses and their cultural legacy within an area.

One of the challenges involves determining the appropriate scale and level of generalization for characterization. A CLA study should offer a level of detail sufficient to identify major categories of human activity that resulted in the production or deposition of important cultural heritage resources in an area. Detail should not be so great as to create historical noise that can obscures important influences and layers of change within each category and add unnecessary research costs.

CLA should capture major patterns of human activity over time at a sufficient scale to identify highly important individual resources; for example, a sacred tribal place or an especially famous or individually outstanding historic shipwreck. CLA should identify the general composition and known and likely locations and distribution of cultural heritage resources. It should produce landscape contexts for evaluating resources in their own cultural terms (in the case of tribal, indigenous, or ethnic landscapes) and that identify their larger influence in history, culture, and the environment. In addition to helping to determine appropriate locations for development, these contexts provide a focus for meaningfully advancing the Section 106 process of the NHPA and in meeting NEPA requirements. This approach was most fully expressed in the energy landscape section of the Rhode Island's Ocean SAMP.

CLA Questions

The CLA questions guiding the Rhode Ocean SAMP, with the adaptations offered below provide a solid starting point for a CLA characterization of potential sites for alternative energy on the ocean:

- What major cultural groups have used this place?
- What are the most important or visible ways that each group used this places?
- Over what time frame have these groups used this place?
- What are the principal specific human practices that have most reshaped or sustained the coastal or marine natural environment of the place?
- What evidence of these activities exists or might exist in the physical landscape, the archaeological resources, or the practices and memories of living cultures?

- In what ways do specific cultural heritage resources link to human stories and knowledge of associated with this place?
- In what ways have the identified cultural heritage and landscapes and their underlying history influenced the ecological and cultural resilience of this place?

Cultures

Although the United States is a culturally diverse nation, in most instances the number of specific cultures and major categories of use found within a distinct geographic area is limited. There may be multiple tribes or indigenous groups with long human histories of an area, and a CLA study should attempt capture them all. CLA researchers should be required to consult in a deep and meaningful way with these groups. The appropriate means of consultation will depend on the specific circumstances. In all cases, tribal and indigenous people should have ownership of their own cultural heritage and its interpretation. Historical archaeological resources reflect the period after Euro-American settlement. Cultural resources for Euro-American sources are abundant and leave very pronounced archaeological signatures that cover relatively short time periods often characterized by rapid change.

Uses

CLA research involves coming to grips with general categories that operate across global, national, regional, and local geographic and historical scales and that find expression in presence, absence, composition, and meaning of material cultural resources found within a specific study area. A relatively small number of landscape context categories will usually be sufficient to classify the major types of material cultural heritage resources to be found in a specific area. These contexts may be more or less refined depending on cultural/archaeological complexity of a given area and the scope of the project. In nearly all large U.S. maritime spaces researchers will find historically significant cultural landscapes associated with fishing (including the hunting of marine birds and mammals), military activity, and maritime commerce. These are highly general categories requiring further refinement by identifying the major cultures or large scale actors (such as governments) involved, the time frame involved, and the progression of technologies associated with each group, practice, and time period. Within the context of global and United States history, there are specific events such as wars or the gold rush, or historical processes such as industrialization, of the adoption of the 200-mile U.S. exclusive economic zone that brought fundamental changes evident in the archaeological record. At a regional level in the United States, we find that distinct processes of exploration, frontier settlement, and economic expansion leave large-scale cultural landscapes comprised of underwater and coastal historical archaeological resources.

Evidence

A key to CLA is matching individual questions, cultures, and uses with the appropriate types of available evidence. For the historical period, many questions can be answered through readily available digitized and published cartographic and historical documents. Cultural landscapes that involve living cultures and certain contemporary practices, however, require researchers to engage with people today as well as with the past and move beyond historical and archaeological sources. As indicated elsewhere, documenting cultural landscapes associated with living tribal and indigenous groups is the exclusive province the appropriate representatives of these groups. CLA , however, provides a place where they may choose to express their stories and identify cultural heritage resources facing potential adverse effects. Fully understanding the complexities of fisheries landscapes likewise requires the involvement of fishing communities who possess knowledge of recent history, and of specific natural features such as tides, currents, weather, that can inform research on fishing and other landscape contexts. Experience suggests that living cultures with attachments to the ocean in conducting a CLA project will enhance the consultative process envisaged in NHPA and NEPA.

While abundant historical and archaeological evidence exists to study many of the most common historical cultural heritage resources found in United States waters, it is unevenly distributed and often heavily skewed towards the years after 1850. Maritime historical materials tend to become quite abundant after the American Civil War when bureaucratic reforms brought new levels of government accountability and administrative reform. A great deal of historical evidence survives for commercial shipping, although much of the most specific material is buried in court records, archives, and private libraries. Military matters likewise have left a rich and often nearly impenetrable repository of archival and published sources. Other vital areas of activity, most notably commercial fishing, are not well represented in the historical record. While the business side and technological aspects of fishing may be well understood, the actual fishing practices often remain unknown. The losses of smaller fishing vessels often escaped recording in government or insurance shipwreck lists. The archaeological record embedded in cultural landscapes may offer the only robust means for fully assessing the cultural history of fishing as well as its impacts on coastal and marine ecosystems.

Breaking Down Categories

Determining the level of specificity and identifying categories will depend on the research design and the history of the area. We offer three examples associated with pervasive categories of human activity likely to leave material cultural heritage resources (Table 1).

Table 1

Categories of Cultural Landscape

<table>
<tr><th colspan="4">Representative Category Breakdown for Three Principle Landscape Use Categories</th></tr>
<tr><td rowspan="8">Maritime Commercial Landscape</td><td rowspan="2">Passenger</td><td>Sail Powered</td><td></td></tr>
<tr><td>Steam</td><td></td></tr>
<tr><td rowspan="4">Natural Resources</td><td>Lumber</td><td></td></tr>
<tr><td>Stone</td><td></td></tr>
<tr><td>Ore/Minerals</td><td></td></tr>
<tr><td>Agricultural Products</td><td></td></tr>
<tr><td rowspan="2">Energy</td><td>Coal</td><td></td></tr>
<tr><td>Petroleum</td><td></td></tr>
</table>

		Other	
Military Landscapes	Defensive	Coastal fortifications	
		Coastal defense and utility vessels	
		Discarded equipment/dump sites	
	Operational	Combat or military support craft – lost in war or peace	Ships
			Planes
			Submarines
		Merchant vessels lost through military action	
	Experiment al	Shore-based testing facilities	
		Naval testing grounds	Ordinance remains
			Aircraft
			Craft sunk for testing
Fishing Landscape	Tribal/ Indigenous	Pre-European contact	
		Post-European contact	Subsistence – non-market
			Subsistence - market
	Euro-American	Non-Motorized	Inshore
			Deepwater/Offshore
		Motorized	Inshore (minimal bottom disturbing, net, hook or trap)
			Inshore (Bottom disturbing mobile trawl, dredge)
			Offshore (minimal bottom disturbing, net, hook or trap)
			Offshore (Bottom disturbing mobile trawl, dredge)

The choice and level of specificity employed in developing landscape contexts will depend on the cultural complexity of the study area as wells its desired outcomes. Identifying resources for the purposes of avoiding adverse effects on areas with concentrations cultural heritage resources that may be eligible for the National Register of Historic Places, or that might represent a threat to human or environmental safety can likely be done by employing fairly general levels of classification. Capturing the meaning of these resources and connecting them with specific communities, cultures, or interested user groups requires more analysis. Extracting the environmental information inherent in these resources involves yet more intensive levels of geospatial and historical analysis and may include archaeological fieldwork.

Developing a more comprehensive management plan will require developing each context sufficiently so as to capture the meaningful heterogeneity of resources embedded in cultural landscapes and the relationships between them. "Meaningful" is admittedly a subjective line to draw, but it certainly involves identifying those important events or processes taking places at various geographic scales that are discernable through individual cultural heritage resources and landscapes at the local level.

3.3.4. Conclusion

The Cultural Landscape Approach (CLA) bridges traditional historic preservation-based approaches to maritime heritage resource management and the broader consideration and integration of human factors in the environment called for by EBM, Coastal and Marine Spatial Planning, and the National Ocean Policy. To summarize, we close with a quote describing CLA taken from the Rhode Island Ocean SAMP:

Through geographical representation and spatial analysis, interdisciplinary research, and multi-cultural interpretive frameworks, CLA makes visible the multiple connections between human and the natural environment in specific places and at different times. It offers one direction for meaningfully incorporating historical change into spatial analysis and coastal and marine planning and management. More than just a method of historic preservation, CLA offers ways to analyze historical patterns and relationships that relate directly to the use of ecosystem services and their effects on the natural environment. (Rhode Island Coastal Resources Management Council 2010).

3.4. Cultural Landscape Approach: Stepwise Framework

As stated previously, CLA does not impose a quantitative model on the qualitative human dimensions of marine environments. However, it brings increased order and coherence to the characterization and management of cultural heritage resources and better understanding of the human dimensions of environmental impacts. CLA operates at multiple geographic scales and at many levels of detail, from the broad to the very fine grained. The schematic below (Figure 1) represents a stepwise conceptual implementation of CLA. The process and relationships described below are consistently driven and guided by CLA principles and types of questions described above and employed in the Rhode Island Ocean SAMP.

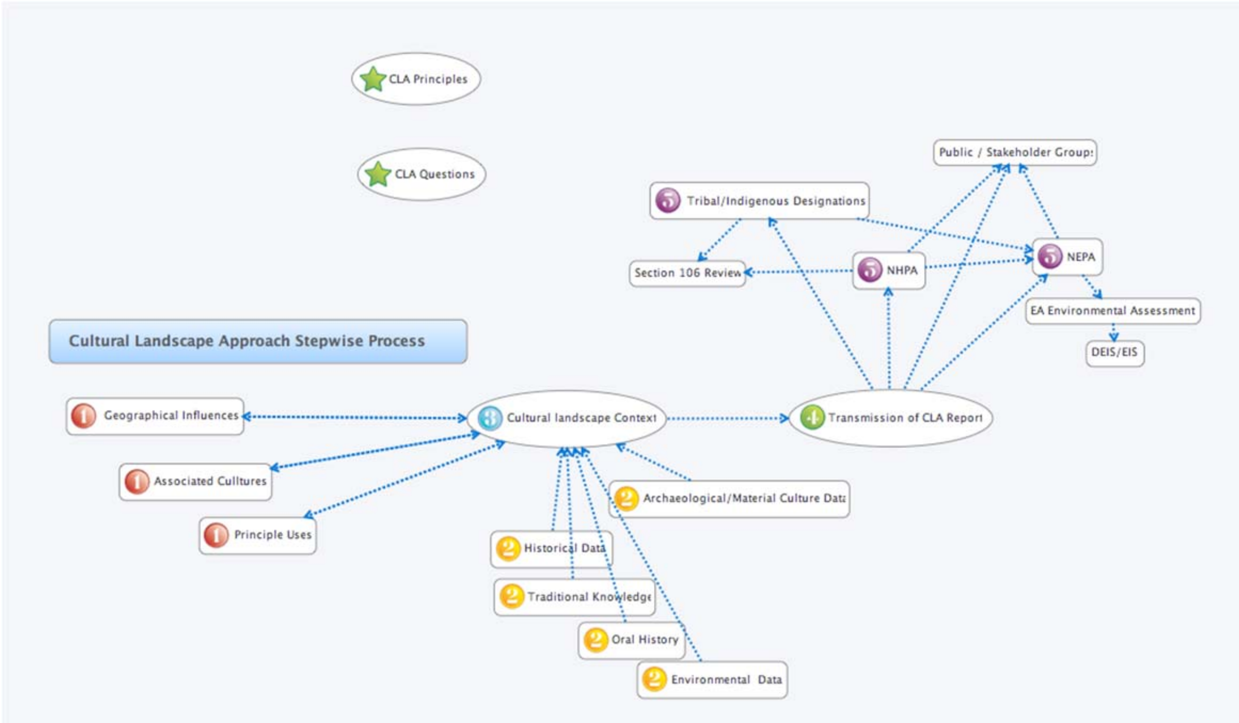


Figure 1. Cultural Landscape Approach Stepwise Process

3.4.1. Step 1. Broad Identification of Geographical/Natural factors, Cultures, and Uses

CLA begins after the geographic boundaries of a study area are established. The first step involves a broad identification of the major geographic/natural features that have consistently influenced human uses of the area, principal cultural groups, and major uses of the area. Research with practical starting points based on widely acknowledged understandings of place, people, and uses, and then works deeper into the landscape through the identification of cultural heritage resources and of the human and natural factors that shaped them. The schematic indicates two-way directional lines between Steps 1 and 3; this reflects the iterative aspects of CLA. The data collected and organized in Step 2 and integrated and analyzed in Step 3 will lead to more complete and accurate representations in Step 1; and feedback through Steps 2 and 3.

Geographical Influences

In a marine environment these might include, for example, tides and currents, prevailing winds, seasonal weather and fish patterns, water depths, composition and habits of living marine resources, landforms such as prominent headlands, geological composition of benthic areas, proximity to protected harbors, and availability of nearby freshwater. These kinds of features or forces tend to exercise important influences on any people from any time period using the marine environment. How these influences are experienced and expressed in cultural heritage resources depends on a variety of human factors analyzed for each cultural landscape context.

Associated Cultures

Researchers should identify principle cultural groups associated with the study area. The identification of tribal and indigenous cultures may be especially challenging, but is crucial given the long history of human uses of coastal and marine environments. Often such information is difficult to access through the written record. Or, if recorded, should be carefully evaluated to take into account historical biases. For the pre-European contact periods, the oral histories of living cultures and archaeological evidence may offer the only significant sources of data. For the post-contact period, published historical sources will usually provide enough detail to identify important groups.

Principle Uses

While every area is potentially unique, coastal and ocean spaces are subject to major types of use over time. Nearly every substantial area of the nation's coastal and ocean waters has been used for the hunting/harvesting living resources, military activity, and commercial navigation. In particular areas one might find extraction for resources such as sand, recreation, or spiritual/religious activity. In CLA, defining uses begins with a best guess identification based on major historical patterns and readily available local sources. It is important to understand that CLA is an iterative process where knowledge is consistently refined through the accumulation, interpretation, and integration of new information.

3.4.2. Step 2. Data Collection and Preliminary Interpretation

Many kinds and sources of data are available and necessary for developing a cultural landscape context (Step 3). In Step 2, research identifies the data needed to flesh out, refine, and expand the understanding of geography, people, and use indentified in Step 1. It is important to understand that Step 2 involves the collection of interdisciplinary data about human and natural factors. Identification of archaeological or other culturally important sites without the integration of environmental and additional historical and cultural factors does not constitute a CLA study. The specific types of data and level of detail required in Step 2 will depend on the complexities of the survey area and the study goals and is suggested in the example CLA category breakdowns offered above. The specific types of data required and their methods of collection and analysis are discussed more deeply in the Archaeological Sensitivity Analysis section (Section 4.0). Each type of data is evaluated in its own terms, before integration with other data in Step 3.

3.4.3. Step 3. Defining Cultural Landscape Contexts

A CLA study involves the development of one or more cultural landscape contexts that identify the principle themes and cultural heritage issues and resources associated with a study area. Developing the context requires placing the historical, cultural and spatial analysis of the interdisciplinary data from Step 2 against the backdrop of the CLA questions of geography, people, and use associated with Step1. An individual landscape context can be defined by a principle human use such as fishing or military activity, or through cultural identity such as tribe, national, or ethnic affiliation. Other categorizations are also possible. The choice of the landscape context theme will depend on local conditions identified in Step 1, and the composition of data and resources identified and analyzed in Step 2. It is in the skillful effort to identify new contexts and relationships where the fresh understanding of the human and ecological history of an area may begin to emerge. This was the case in the Rhode Island Ocean SAMP's energy landscape. Only through the application of archaeological, historical, and geographical/geophysical data did energy appear as the theme most influencing commercial shipwrecking and development of maritime infrastructures such as life stations, harbors of refuge, and improved lighthouses.

The landscape context is the step where cultural meaning or historical importance is associated with specific cultural heritage resources such as potential and confirmed archaeological sites, submerged paleo-landscapes, or intangible resources such as systems of belief. Creating the landscape contexts is the most challenging, and in management terms, the most important aspect of CLA. The contexts become the operational mechanism that allow for the rigorous and open-ended integration of multiple cultural and disciplinary perspectives. The development of the contexts precedes any NEPA and NHPA decision-making—the goal here is to establish the major cultural heritage connections and issues associated with the study area and identify and interpret resources of interest. The landscape context makes CLA highly adaptive as a management framework as new contexts may be readily added and older ones amended if the accumulation of new data or the additional of new cultural groups warrants.

3.4.4. Step 4. Transmission of CLA Results

Step 4 is the transmission of the results of the CLA study to appropriate agencies, tribes, community/stakeholder groups, and the public. In this step cultural heritage resources and their cultural and environmental contexts are directed to appropriate areas of review and decision-making. The distinguishing of Steps 3 and 4 helps to separate the collection and interpretation of CLA data from the regulatory decisions. This creates something of a firewall that can help reduce the chance or perception of conflicts of interest between research and regulation. The direct transmission of CLA results (in their appropriate forms) to stakeholder groups and public as part of Step 4 brings additional transparency to the review process and offers important education and outreach opportunities that may help improve public understanding and dialog.

3.4.5. Step 5. Regulatory Application

In Step 5, actions are taken with regard to cultural heritage resources under NEPA, NHPA, Tribal Designations, or other decision-making bodies. The Step 5 actions are based on the content of individual or combined cultural landscape contexts. The Step 3 landscape contexts should increase the evidence of human/environment interactions available for project planning and environmental review. The Step 3 landscape context characterization will lead to a stronger understanding of the relative historical, cultural, and environmental significance of cultural heritage resources. It also may provide a more nuanced understanding of the cultural significance of specific natural resources and areas. Ultimately, Section 106 review will be working from much stronger evidentiary and more culturally inclusive foundations while NEPA review will be able to better accommodate cultural heritage data in making decisions regarding project impacts on human and natural environments. At minimum the results of CLA study would inject an important level of temporality into environmental assessment, answer calls for better integration of the human element in ecosystem-based management decisions, and serve as important and relatively cost-effective step in an Environmental Assessment (EA) and EIS processes.

4. ARCHAEOLOGICAL SENSITIVITY ANALYSIS (ASA) AND PREDICTIVE MODELING

The use of geospatial analysis to determine archaeological sensitivity or to create archaeological site models has increased substantially in recent years. Nowadays, archaeologists seldom consider site distribution to be random. The variables that explain site distribution, however, differ by resource type. Different sets of variables help explain pre-contact site distribution as opposed to historic site distribution.

All techniques for archaeological site modeling or sensitivity analysis aim to explain, or at least partially explain, site distribution patterns whether it be for research or resource management. Models developed and techniques used over the past 15 years or so have been almost universally GIS-based. These models and techniques are summarized below.

4.1. PREDICTIVE MODELING

A true archaeological-site predictive model is mathematical in nature and is backed by sound statistical analysis. The result is the establishment of predictive zones representing a high, medium and low probability of archaeological sites being represented in those areas. Model development is usually a multi-year process that includes extensive initial survey work to gather baseline data and address previous survey bias, model development, and finally model testing and refinement. The end product is robust enough that a high percentage of sites, ~80%, fall within high or medium zones, while those zones themselves only account for a moderate to small part of the relevant geographic area, ~25%. Most archaeological predictive models in the United States are GIS-based and have been focused on Indigenous site patterns. They center on creating environmental zones that are more likely to contain archaeological sites. Those zones are created by use of independent variables such as elevation, slope, soil type, and distance to fresh water. Examples of predictive models include the Minnesota Archaeological Predictive Model, (Minnesota Department of Transportation 2005) which purports to predict pre-1837 archaeological sites in the state, and also archaeological site predictive models in Rhode Island and Massachusetts (Massachusetts Historical Commission 1982; Mulholland 1984; Dincause 1968; Dincause 1974; Thorbahn 1982; Rhode Island Historic Preservation and Heritage Commission 1982; Rhode Island Historic Preservation and Heritage Commission 1986) It is certainly possible that predictive models could be developed for underwater historic site locations – for example shipwrecks - but there have been few efforts to do so. It is more common to use a technique called Archaeological Sensitivity Analysis for historic sites (see below). As part of the work for this project, researchers experimented with enhancing ASA so as to provide something closer to a predictive model.

4.2. PALEO-ARCHAEOLOGICAL LANDSCAPE AND ENVIRONMENTAL RECONSTRUCTION

Pre-contact, archaeological site predictive modeling is enhanced considerably by paleo-archaeologicial landscape reconstruction and paleo-environmental reconstruction – both of which require the collaboration of archaeologists with earth scientists. The process starts with an archaeological understanding of the relationship between Native American sites and the environment – particularly the locational relationships between sites of human habitation and topography, natural resources and fresh water. By understanding the paleo-environment, paleo-climatic change, and the paleo-landscape it is possible to identify areas that are more likely to contain prehistoric archaeological sites. At the same time, it is also possible, through an understanding of aspects such as weathering, erosion and depositional patterns, to identify exposed or nearly exposed ancient landscapes and relic surfaces – i.e. those that lie close to the modern land surface.

4.3. Archaeological Sensitivity Analysis

Archaeological Sensitivity Analysis (ASA) is a technique used by archaeologists and historians to designate certain areas as more archaeologically sensitive than others. In that sense it is closely allied to predictive modeling. Those designations are based on historic, archaeological, GIS, geophysical, and site-specific studies as interpreted by an experienced professional archaeologist and/or historian. In general, ASA has been used for assessments of historic rather than prehistoric site patterns and sensitivity. (Mather and Watts 1998; Mather and Watts 2002) All the data is geo-spatial in nature but not necessarily quantitative. ASA is not usually built upon a statistical model. More frequently, ASA is based on exploratory data analysis and is dependent on the capacity of the field professionals to see patterns, make judgments and divide an area into zones of archaeological sensitivity. Those zones tend to be 3 or 5 in number and range from Highest Sensitivity (areas that contain known cultural resources that are on, or have been determined eligible for inclusion in, the National Register of Historic Places) to Lowest Sensitivity (areas that have experienced low levels of documented human activity or that have experienced extensive disturbance. They contain no known historic or archaeological sites, a finding that has been confirmed through geophysical survey and archaeological inspection). Certainly ASA can and has been applied to submerged environments, for example by Mather and Watts in the James River and Charleston Harbor (Watts and Mather 1996; Watts and Mather 1997).

4.4. Predictive Modeling Discussion and Recommendations

Just as archaeologists have developed predictive models for pre-contact sites on land, it is certainly possible that similar efforts could be made underwater. Underwater pre-contact archaeology is still in its infancy, but it is clearly one of the most important new directions for the discipline. Unfortunately, underwater archaeology tends to be more costly than its land based counterpart, and the costs and time associated with developing a statistically valid pre-contact predictive model underwater would exceed similar efforts on land. Given that predictive modeling on land is already expensive and time consuming, similar efforts underwater at this time, therefore, would be impractical. The Minnesota predictive model, for example, which was a terrestrial project, took 4 years to complete (Minnesota Department of Transportation 2005). A similar project underwater could easily cost twice as much and take twice as long. With that said, a limited paleo-archaeological landscape reconstruction is more practical. Such an undertaking could identify areas of pre-contact archaeological sensitivity, and when combined with an enhanced version of ASA for historic sites has great potential as a tool for assessing the impacts of offshore alternative energy development.

4.5. Paleo-Archaeological Landscape Reconstruction Discussion and Recommendations

Paleo-archaeological landscape reconstruction is a critical component of any baseline study for offshore alternative energy assessments. It is particularly important in areas of the continental shelf that have experienced significant sea level rise since the last glacial maximum (LGM). In some areas this can be upwards of 70 meters. These areas of the seafloor possess significant potential for submerged pre-contact archaeological sites.

A preliminary paleo-archaeological reconstruction is achievable as part of baseline alternative energy studies. It requires, however, substantial integration of disciplines and methodologies. Using a combination of geological knowledge, sub-bottom data, side scan sonar data, and coring, it is possible to partially reconstruct the landscape prior to inundation and marine sedimentation. As a result it is possible to identify: areas that were sub-aerially exposed, relic surfaces, glacial lakes, relic riverbeds and the sedimentary regime. While this, by itself, falls short of a predictive model, it does identify areas that could contain archaeological material and, therefore, have greater archaeological sensitivity.

One significant issue is the extent of coring required for paleo-archaeological landscape reconstruction. This requirement can only be determined on a case-by-case basis, but a logical path would to be to determine overall project coring requirements with input from archaeologists, geologists and physical oceanographers and to use the data in an integrated, interdisciplinary manner. Certainly knowledge about the existence of human populations in areas that were sub-aerially exposed should be one of the driving factors in any coring decision-making process.

4.6. Archaeological Sensitivity Analysis Discussion and Recommendations

Archaeological Sensitivity Analysis holds great potential as a tool for offshore alternative energy baseline studies for submerged cultural resources. It can identify areas with greater likelihood for containing archaeological resources and can help developers and managers with assessment of time, costs and threats to cultural resources. A GIS-based ASA could also dovetail well with the results of paleo-archaeological landscape reconstruction. The question remains, however, to what extent can ASA for historic cultural resources, like shipwrecks, be expanded or enhanced so as to add rigor to the process. In an attempt to do this, we used data from the Ocean SAMP to refine and test ASA so as to better explain historic shipwreck distributions in Rhode Island waters.

4.7. Using the Ocean SAMP to Improve ASA

Between 2007-2010, a team of 60 researchers, policy experts, and educators from the University of Rhode Island, representing four colleges (Ocean Engineering, Graduate School of Oceanography, College of Environmental Life Sciences, and Arts and Sciences) worked to develop a Special Area Management Plan (SAMP) for Rhode Island Sound (Rhode Island Coastal Resources Management Council 2010). The three-year effort to describe and characterize Rhode Island's offshore resources was in response to a state mandate that 15% of Rhode Island's energy would come from renewable resources, primarily offshore wind farms.

The Ocean SAMP promoted a balanced and comprehensive ecosystem-based, adaptive management approach to the development and protection of Rhode Island's ocean-based resources, including the siting of offshore renewable energy. The final document sought to ensure that sound science and lessons learned from all over the world would strongly inform the establishment of new ocean policies for management decisions in Rhode Island waters. These policies address benthic and pelagic ecosystems, fish resources and essential fish habitat, fisheries, birds and bats, sea turtles, marine mammals, cultural and historic issues (including tribal concerns), global climate change, and human activities including offshore renewable energy. As a result of extensive mapping and multidisciplinary data gathering, the waters of Rhode Island sound provide an ideal opportunity to apply and expand ASA so as to provide an improved tool for offshore alternative energy siting as related to submerged cultural resources.

4.7.1. Introduction

The Ocean SAMP study area is located is located in the northeastern U.S., along the south shore of Rhode Island (Figure 2). The shoreline is largely oriented in an east-west direction, and includes Block Island Sound, Rhode Island Sound, and open ocean. This area has been important to maritime activities for over 400 years and represents a crossroads between multiple heavily used waterways: Narragansett Bay, Long Island Sound, Buzzards Bay, and Vineyard Sound.

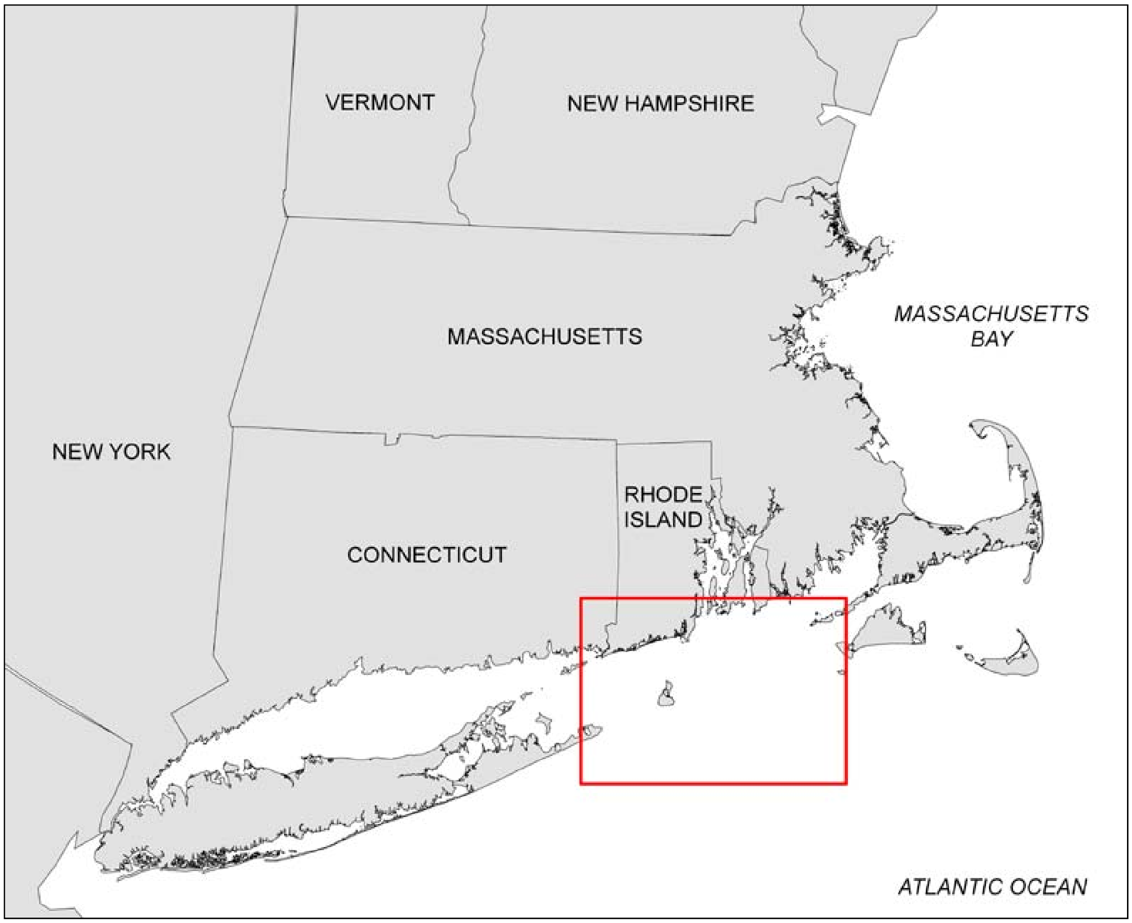


Figure 2. Rhode Island Ocean SAMP Study Area

The purpose of our work was to use Ocean SAMP data to inject more rigor into ASA, thereby improving ASA to the point that it could provide something closer to a predictive model (Rhode Island Coastal Resources Management Council 2010). While we use the term predictive model in the text that follows, our results cannot be considered a true archaeological predictive model in the strictest sense.

4.7.2. Source Data

The following data and their sources were used in the study.

1. Known shipwreck locations (n=119) – from a database developed by URI researchers for the Ocean SAMP.
2. Random control points (n=131) – a series of random points were generated using Arc GIS software (Environmental Systems Research Institute, Redlands CA) across the study area. To prevent random points from being coincident with known wreck locations, no random points were allowed to be within a 500' (152 m) radius of a known shipwreck.
3. Water depth
4. Seabed slope

5. Standard deviation (STD) of the seabed slope – the STD of the slope highlights areas where the slope changes abruptly and could indicate the presence of turbulent surface waters and/or currents.
6. Commercial vessel counts – vessel traffic was obtained from the Automatic Identification System (AIS) over an 8 month period from Sept. '07 – Apr. '08. A 1km grid was laid across the study area and the number of vessel points within each grid cell was summed. (U.S. Coast Guard Navigation Center)
7. Distance to shore
8. Distance to a navigation aid – as contained within the NOAA Electronic Nautical Charts (ENC).
9. Distance to a known cautionary area – obtained from the NOAA ENCs.
10. Distance to military testing areas – obtained from the NOAA ENCs.
11. Distance to closest port – port locations were obtained from the NOAA ENCs.
12. AWOIS point density – the Wrecks and Obstructions (AWOIS) database is maintained and distributed by NOAA's Office of Coast Survey. It is freely available and contains point locations for submerged wrecks and obstructions within U.S. coastal waters. The AWOIS The AWOIS points were converted into a density grid to minimize the effects of overlap between the Rhode Island and AWOIS datasets, and to broaden their influence over the study area. Figure 2 shows the relationship between the original AWOIS points and the calculated point density surface.

ArcGIS software was used to compute all spatial metrics. The data above represents those used in the final analyses. The original more expansive list of data used is as follows:

1. Depth; 2. Seabed slope; 3.Commercial vessel traffic counts; 4. Distance to shore; 5. Distance to another AWOIS wreck; 6. Distance to closest navigation aid; 7. Distance to shore; 8. Distance to vessel caution areas; 9. Distance to military testing areas; 10. Distance to historic fishing grounds; 11. Distance to closest port; 12. Distance to mobile gear fishing grounds, winter; 13. Distance to mobile gear fishing grounds, spring; 14. Distance to mobile gear fishing grounds, summer; 15. Distance to mobile gear fishing grounds, fall; 16. Distance to fixed gear fishing grounds, winter; 17. Distance to fixed gear fishing grounds, spring; 18. Distance to fixed gear fishing grounds, summer; 19. Distance to fixed gear fishing grounds, fall; 20. Distance to recreational fishing grounds, winter; 21. Distance to recreational fishing grounds, spring; 22. Distance to recreational fishing grounds, summer; 23. Distance to recreational fishing grounds, fall.

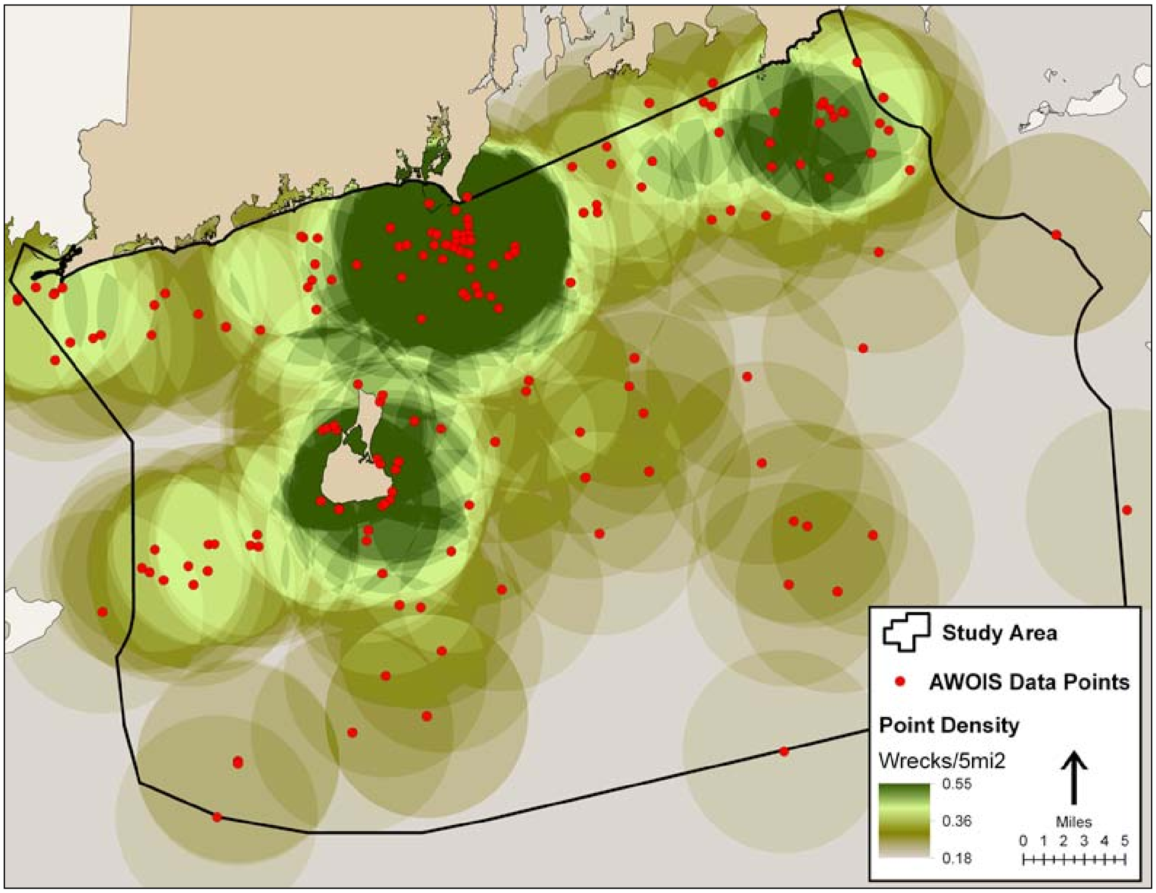


Figure 3. Original AWOIS data points with the calculated point density surface

4.7.3. Statistical Process

The known wreck locations (n=119) were merged with the random points (n=131) to create a single working dataset (N=250). At each point location, values of independent variables identified in the previous section were recorded. These variables were evaluated for their respective predictive ability in a logistic regression model implemented using PROC Logistic (SAS Institute 1999) in the SAS software Version 9.2 of the SAS System for Windows. (Copyright © 2008 SAS Institute Inc.) Logistic regression is ideal for these data because of the model's ability to explain a single dichotomous dependent variable using multiple, continuous independent variables (Peng et al. 2002). A stepwise variable selection procedure was run to identify which of the variables had the greatest influence on shipwreck location. Of the original 10 predictor (independent) variables, only water depth and AWOIS point density were determined to be significant to the final model.

Using these two variables as input, a logistic regression analysis was run to calculate both the modeling coefficients and distributions for the predicted probabilities of shipwrecks versus non-shipwrecks (Figure 4). Results from the final logistic regression model are shown in Tables 3 and 4.

Table 2

Analysis of Maximum Likelihood Estimates

Parameter	Estimate	Standard Error	Wald Chi-Square	P-value
Intercept	0.7118	0.6284	1.2831	0.2573
Depth	0.0176	0.0048	13.4892	0.0002
AwoisDensity	6.1620	1.6074	14.6951	0.0001

Table 3

Predicted Probabilities and Observed Responses

Percent Concordant	80.5
Percent Discordant	19.3
Percent Tied	0.2
Pairs	15589
Somers' D	0.612
Gamma	0.614
Tau-a	0.307
c (ROC)	0.806

The predicted probability histograms in Figure 4 show a definite separation between actual shipwreck points and the random non-wreck points. Review of the histograms indicates that probability values less than 0.36 are most likely non-wrecks, while values greater than 0.61 are more likely to be wreck locations. Predictions between these two values are somewhat muddled and could be either. In general, the model is able to distinguish wrecks from the random locations, but does a better job of predicting non-wreck locations.

"Measures of association" are used to evaluate predicted versus actual outcomes to determine if high probabilities are actually associated with events, and low probabilities non-events (Peng et al. 2002). In this case, high probabilities indicate the presence of a shipwreck, while low probabilities indicate that no wreck is present. Goodman-Kruskal's Gamma and Somers's D are two such measures listed in Table 2. Both have a calculated value of 0.61 that can be interpreted as there being 61% fewer errors made in predicting a wreck location by using the estimated probabilities than by chance alone (Demaris 1992; Agresti 2007).

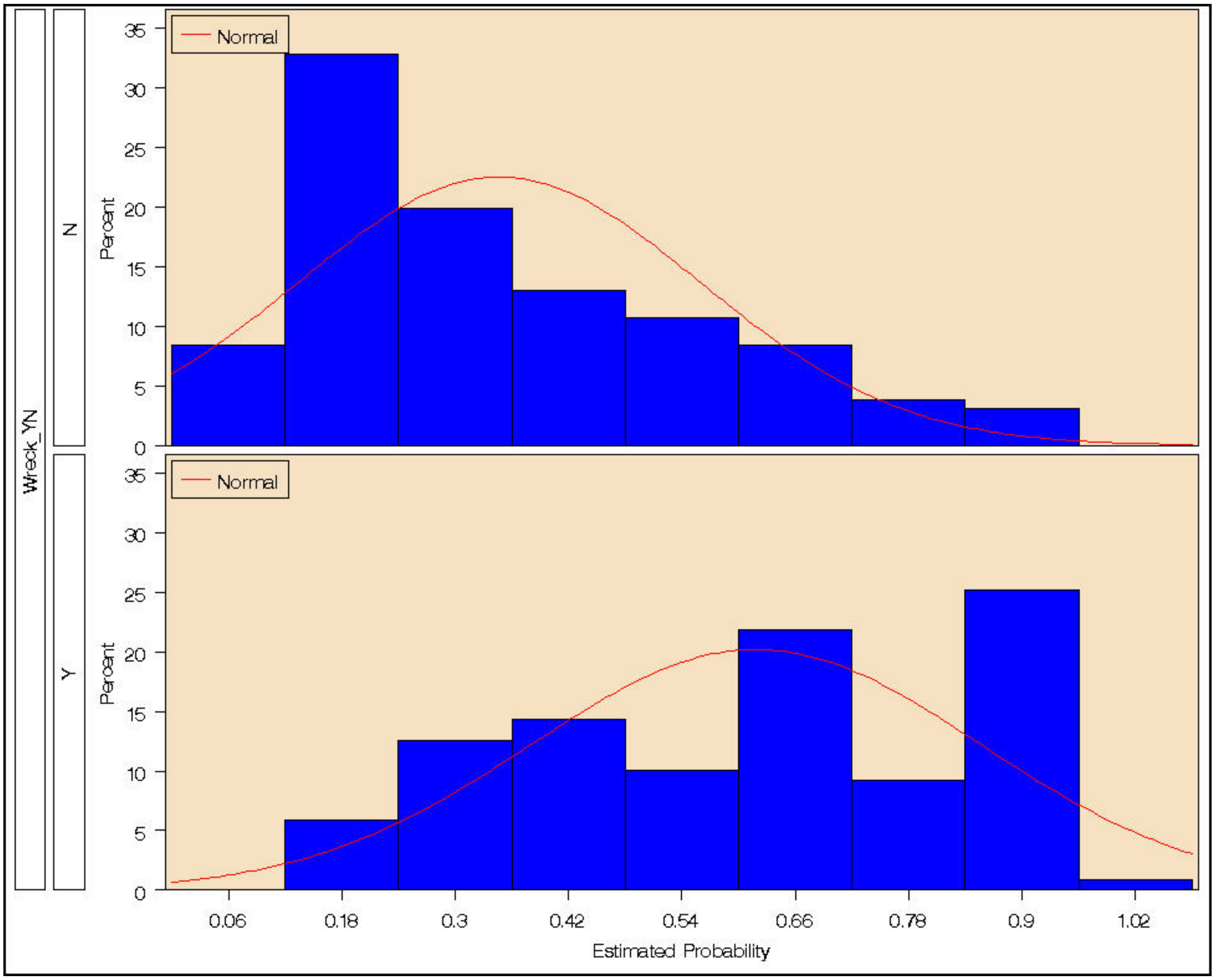


Figure 4. Distribution of predicted probability for non-wrecks (top) vs. shipwrecks (bottom).

This ability to predict wreck locations is better than random chance, with a c statistic value of 0.81. The c statistic is commonly known as the area under the Receiver Operating Curve (ROC). Output for the c statistic range from 0.5 to 1.0, with a value of 0.5 indicating that the model was no better than randomly assigning outcomes. This means that for all possible wreck/non-wreck point combinations, 81% of the time the model assigned a higher probability to the known wreck locations versus the non-wreck sites (Peng et. al. 2002, Agresti 2007).

4.7.4. Mapping

Using coefficients from the logit model, it was possible to calculate a probability surface for the study area using the following equations:

$$f(\mathbf{XB}) = \frac{1}{1 + e^{-XB}}, \qquad \mathbf{XB} = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

where x_1 is recorded depth and x_2 recorded AWOIS density at each of the 250 locations. 2 are coefficients associated with depth and AWOIS density respectively. f (XB) is interpreted as the estimated probability that a shipwreck is present at a given location. Figure 5 shows this estimated probability surface in conjunction with the AWOIS database points and actual shipwrecks.

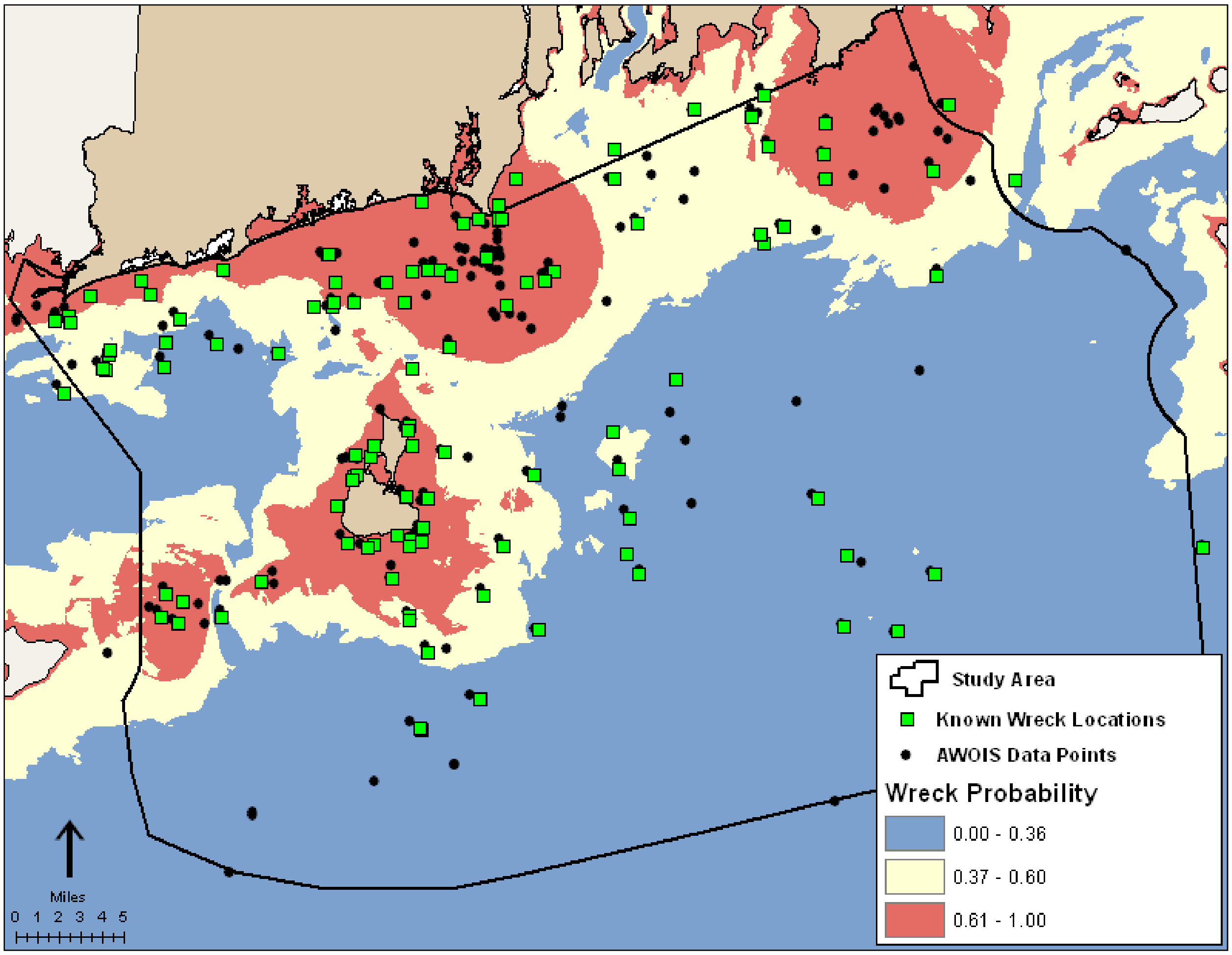


Figure 5. Probability surface displayed with both known wreck locations and AWOIS data points. Break values for the probability classes were obtained from the predicted probability histograms.

4.7.5. Discussion

Our results provided an indication for how well our method and data predict wreck locations, but it was also possible to use the probability surface to evaluate how these measures predict existing wreck locations. Our study was designed to address the following questions:

1. Using our method, what locations throughout the study area have the highest probability of containing a shipwreck?
2. How well does the predicted surface capture known wreck sites?

Figure 4 shows the distribution of known wreck locations along with the areas that pertain to low (≤ 0.36), medium (0.37-0.60), and high (≥ 0.61) probabilities of containing an actual wreck. Shallower depths and higher concentrations of AWOIS points generally yielded the highest probability areas.

The quantitative measures from the analysis are listed in Table 4. It can be seen that 56% of the known shipwreck sites fall within the highest probability area. The highest probability class encompasses only 15.7% of the total study area (230 mi²). By focusing only on the highest probability areas, a researcher would be targeting 56% of the known wrecks while only having to survey 15.7% of the total area. This does not, of course, make any judgment as to the relative value of one shipwreck over another.

Table 4

Quantifying Model Effectiveness

Probability of wreck	Area (mi^2)	% of Total	# wrecks (n=119)	% of Total
Low	945	64.4	22	18.5
Medium	283	19.3	28	23.5
High	230	15.7	67	56.0

4.7.6. Conclusions

This work has shown that developing a predictive statistical model to locate shipwreck locations and enhance ASA holds promise, although, at present, it falls short of the predictive models used by archaeologists on land. By accessing two freely available data sets, bathymetry and the AWOIS database, researchers can make educated determinations as to areas that are more likely to contain shipwrecks. How well this applies to areas beyond Rhode Island has yet to be determined. Nevertheless, this protocol can be considered one tool in assessing the likely impact of offshore alternative energy on submerged historic cultural resources.

Future studies might look at both refining the predictive variables and evaluating the applicability of transferring the methodology to other geographic locations.

4.8. Protocols for Applying ASA

Across the United States, there is considerable variation in our understanding of submerged cultural resources. In some areas, knowledge is fairly advanced, while in others it is virtually non-existent. The applicability of protocols for ASA in different parts of the United States is, therefore, also variable. The following protocols are generally applicable and transferable, but BOEMRE should develop specific and targeted research plans for each area under considered for offshore renewable energy. These plans should take account of the state of cultural resource knowledge in each area and area-specific logistics and practicalities.

4.8.1. Inventory and Database Development

It is impossible to manage submerged archaeological sites without an inventory of known sites, even if that inventory is preliminary in nature. The first step for developing an ASA is to generate a database of known shipwrecks and other submerged cultural resources in a region. This product will not be exhaustive, but it should reflect information that is available with reasonable effort. Compiling a complete database would almost certainly take years of archival work and archaeological research, and a scale of effort that is prohibitive for baseline studies.

At a minimum, a submerged archaeological site inventory should include all pertinent information for the study area from the following sources:

NOAA's Automated Wreck and Obstruction Information System (AWOIS).

This database is compiled and managed by NOAA's Office of Coast Survey. It contains more than 10,000 wrecks and obstructions divided into 16 regions. The data is readily available at http://www.nauticalcharts.noaa.gov/hsd/awois.html. The quality of the AWOIS database is variable and includes more than shipwrecks. Many AWOIS entries are unconfirmed and in some cases the locational information is very approximate (sometimes the error is several miles).

State Archaeological Files

Each State maintains its own archaeological site files managed by the State Archaeologist and the State Historic Preservation Office and/or Officer (SHPO).

There is little uniformity, however, in the extent of the files from one State to another or the way that the data is managed. There are also great differences in the extent to which official State databases include underwater archaeological sites. In some cases, the state database has an extensive list of shipwrecks and other submerged cultural resources on it, whereas in others the number of underwater archaeological sites in the state's database might be zero.

Federally Protected/Regulated Areas

Some coastal, near shore and offshore areas are protected and managed state, federal agencies or the military. Principle examples include the National Parks, NOAA National Marine Sanctuaries and other Marine Protected Areas. In most cases, these agencies have jurisdiction over cultural resources and have some level of inventory. When this is the case, requests for data and information about submerged cultural resources should be made to the appropriate park or area superintendant. When the area in question is a military testing ground, information about testing and/or targets sunk may be publically available, frequently through the National Archives. In other cases, it might require contact with the appropriate navy commander or the Navy Historical Center, in Washington DC.

Northern Shipwrecks Database

This database is compiled by a for-profit group - Northern Maritime Research - from historical sources including insurance records and various governmental records. It comprises in excess of 100,000 shipwrecks in North American waters and is available at http://www.northernmaritimeresearch.com/

NOAA - Resource and Undersea Threats (RUST) Database

This is a NOAA database of undersea threats to the environment, including where appropriate, cultural resources. It contains about 7000 shipwrecks in US coastal waters extending out to the edge of the continental shelf. The aim of the database is to be as comprehensive as possible and include all wrecks that contain oil or any other environmentally hazardous material. The data is fairly extensive with about 150 fields for each record (Madrigal 2008).

In addition, there are a number of published secondary sources with shipwreck listings. Some are general overviews like Robert Marx, Shipwrecks of the Western Hermisphere, 1492-1825, while others, such as Donald Shomette, Shipwrecks on the Chesapeake, are regional studies. In the titles below, the more general volumes appear toward the top and the state or region specific ones are lower down. The list is illustrative rather than comprehensive.

- Robert F. Marx, Shipwrecks of the Western Hemisphere, 1492-1825.
- Craig W. Gaines, Encyclopedia of Civil War Shipwrecks.
- William M Lytle, Merchant Steam Vessels of the United States 1807 - 1868.
- Steven D. Singer, Shipwrecks of Florida: A Comprehensive Listing.
- William P. Quinn, Shipwrecks Around Cape Cod.
- David Stick, Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast.
- Donald Shomette, Shipwrecks on the Chesapeake: Maritime Disasters on Chesapeake Bay and Its Tributaries, 1608- 1978.
- Donald Shomette, Shipwrecks, Sea Raiders, and Maritime Disasters Along the Delmarva Coast, 1632-2004.

There are also various diver guides, both in print and online. In Rhode Island, for example, researchers should consult Marlene and Don Snyder's books *Rhode Island Adventure Diving and Rhode Island Adventure Diving II*; and Henry Keatts and George Farr's book, The Bell Tolls: Shipwrecks & Lighthouses, Volume 1, Block Island. For New England as a whole, researchers should consult: //www.wreckhunter.net/

Using accessible databases and secondary historical literature, a preliminary database of submerged cultural resources in a region can be compiled. This will enable, researchers to look for spatial and temporal patterns of vessel loss as well as identify actual or potential highly significant individual sites. The latter should be targeted for attention irrespective of the results of ASA and/or modeling. Criteria for identifying sites as highly significant are provided by the National Historic Preservation Act (see CLA section 3.2.6 above)

4.8.2. Archival and Primary Source Research

There is no region in the country where all shipwrecks and submerged archaeological sites can be discovered through accessing existing databases and working with published sources. In every area, archival and primary source historical research, combined with archaeological survey and groundtruthing would be required. The options for archival and primary source research are extensive and potentially very time consuming. This kind of historical research, therefore, should be targeted so as to:

a. Provide information about archaeological sites, potential archaeological sites and culturally significant places.

b. Provide an understanding of human use of an area as required for CLA (see CLA section 3.0 above)

The following is a list of some types of records that could be consulted. For the most part, these records will be found at State, Regional or National Archives. Other records might be available at academic libraries and/or local historical societies.

- US Army Corps of Engineers Records
- Life Saving Service Records
- Records of the Hydrographic Office
- Coast Guard Records
- Navy Records
- Department of Treasury Records
- Historic Newspapers

Since records of bottom disturbing activities are important for an ASA, the US Army, Corps of Engineer records are particularly important. These track a multitude of bottom disturbing activities including dredging, harbor construction, sand borrow activities and dredge spoil dumping.

4.8.3. Cultural Resource Survey Data

Many coastal and offshore areas in the United States have been the subject of geophysical or cultural resource surveys. The results of relevant surveys should be identified as part of any baseline study and incorporated into the project database. At a minimum, the geographical extent of each cultural resources survey should be identified and any potential cultural resource targets and their coordinates should be listed. For state waters, records of previous cultural resources surveys can be found at the office of the State Historic Preservation Officer. Where surveys have been completed in federal waters under the auspices of a federal agency, that agency should be contacted for copies of the archaeological reports.

4.8.4. Historic Cartographic Analysis

Analysis of historic charts, particularly navigation charts, is an important part of historic site ASA. In many cases these are available on line through the NOAA website <http://www.nauticalcharts.noaa.gov/csdl/ctp/abstract.htm>. In some cases, all, and in other cases a representative sample, of relevant navigation charts should be geo-rectified using a GIS software program such as ArcGIS. Multiple historic data sets should be extracted from the historic navigation charts including hazards to navigation, charted wrecks, navigation corridors, historic anchorages, bridges, wharfs, cable corridors, shoaling, obstructions, shoreline changes, aids to navigation, dumping grounds, docks, harbors, patterns of maritime commerce, and military testing grounds. The result should be variables and data sets that can be displayed and incorporated into an ASA. In some cases, place names can provide clues to possible shipwreck locations.

Other sources of historic maps include, but are not limited to:

- Regional, State and National Archives (including some online access such as American memory from the Library of Congress http://memory.loc.gov/ammem/index.html)
- David Rumsey Map Collection: http://www.davidrumsey.com/
- Norman B. Leventhall Map Center at the Boston Public Library http://maps.bpl.org/
- Perry-Castaneda Library Map Collection at the University of Texas http://www.lib.utexas.edu/maps/map_sites/hist_sites.html

4.8.5. Current Human Usage

ASA should also include current human usage data. Where possible, researchers should include recreational dive sites, recreational fishing grounds, commercial fishing grounds, current vessel traffic, harbors, docks and wharfs, anchorages, current aids to navigation, and charted hazards. Some of this is available through NOAA as ENC data:

http://www.nauticalcharts.noaa.gov/csdl/ctp/encdirect_new.htm. Commercial shipping traffic data, or Automated Identification System data (AIS), is available from a number of online sources including: http://www.portvision.com/products/ais-data-analytics.aspx.

4.8.6. Environmental Data

Sources of environmental data are extensive. Archaeologists should work with an environmental data GIS specialist to gather that data. Some of the most important data are coastlines, bathymetry, tides, currents, wind patterns, geological maps, and surficial geology. The bathymetric data is available through the National Geographic Data Center: http://www.ngdc.noaa.gov/.

4.8.7. Allocation of Sensitivity Zones

ASA uses the capabilities of GIS software to create geo-spatial databases and to analyze relationships between data sets. By overlaying the various historic, archaeological, bottom-disturbing, and geophysical survey coverages, researchers can examine the relationship between areas of historic significance, the level of possible site disturbance, and the level of archaeological survey. Researchers can then divide the study area into zones and assigned a sensitivity rating to each area. Buffering tools can be used to create sensitivity zones around known archaeological sites.

This is not an exact or statistical analysis, but rather a general analysis utilizing a direct historical approach and exploratory data analysis. The results of paleo-archaeological landscape reconstruction should be also included along with a general understanding of site pre-contact site distribution patterns as they relate to environmental variables such as soil, slope, elevation, and distance to fresh water.

For definitions of sensitivity zones, Mather and Watts (2002) used the following:

- Level 1 (identified sites), the highest level of sensitivity corresponds with the location of known submerged cultural resources. These resources have been identified by previous research and have been determined to be eligible for, or have been nominated to, the National Register of Historic Places.
- Level 2 (areas of high sensitivity), corresponds to areas that have intense levels of documented human activity, high incidence of identified archaeological sites, high incidence of historically and cartographically documented shipwrecks and/or other submerged cultural resources, and limited bottom disturbing activity associated with development.
- Level 3 (areas of moderate sensitivity), corresponds to areas that have moderate levels of documented human activity, moderate incidence of identified archaeological sites, historically and cartographically documented shipwrecks and/or other submerged cultural resources and limited bottom disturbing activity associated with development.
- Level 4 (areas of low sensitivity), corresponds to areas that have low levels of documented human activity, no known submerged cultural resources, no historically and cartographically documented shipwrecks and other submerged cultural resources and high incidence of bottom disturbing activity associated with development.
- Level 5 (areas of lowest sensitivity) corresponds to areas previously surveyed for submerged cultural resources with negative results, no known submerged cultural resources, no historically and cartographically documented shipwrecks and other submerged cultural resources and an extensive record of bottom disturbing activity associated with development.

4.8.9. Developing a Probability Surface.

In this report, we have recommended using statistical analysis to develop a more robust version of ASA. This falls short of a true predictive model that has been developed by testing for bias in previous cultural resource surveys, by using an exhaustive list of variables and by field-testing the model after prototype development. Nevertheless, this enhanced form of ASA does appear to have some utility for both cultural resource managers and developers wishing to assess the likelihood of encountering significant historic cultural resource issues in any given area. For the Ocean SAMP we were able to assemble 22 variables as described in section 4.7.2 above. Using logistic regression we narrowed those variables down to 12 and determined which variables best explained historic shipwreck distributions. Logistic regression is ideal for these data because of the model's ability to explain a single dichotomous dependent variable using multiple, continuous independent variables.

In order to develop an enhanced version of ASA researchers should run a stepwise variable selection procedure to identify which of the variables has the greatest influence on shipwreck location. Variables that are statistically significant should then be used in the final set of analyses. Logistic regression is run to calculate both the modeling coefficients and distributions for the predicted probabilities of shipwrecks versus non-shipwrecks. "Measures of association" are then used to evaluate predicted versus actual outcomes to determine if high probabilities are actually associated with events, and low probabilities non-events. Goodman-Kruskal's Gamma and Somers's D are two such measures. Using coefficients from the logit model, it is then possible to calculate a probability surface for the study area. The area should be divided into at least three zones – high, medium and low probability of shipwreck presence.

In the case of Rhode Island Ocean SAMP, described in section 4.7, bathymetry and distance to AWOIS point (both readily available data sets) were used to calculate the probability surface. 56% of the known shipwreck sites fell within the highest probability area, which in turn encompassed only 15.7% of the total study area (230 mi^2). This model has not been groundtruthed and field tested for Rhode Island Sound. Nor have the methods described here been applied to other areas in the United States. Nevertheless as a set of protocols ASA and ASA enhanced with statistical analysis has great potential for offshore alternative energy baseline studies. Further work should be done. As BOEMRE completes baseline studies they should require the creation of probability surfaces so that more data can be acquired to test the general applicability of the various variables and models.

5. RECOMMENDATIONS AND CONCLUSIONS

Faced with global climate change and increasing strategic, financial and environmental issues with fossil fuels, the United States is looking to alternative forms of energy. Included in the matrix of options is offshore alternative energy. The development of wind, wave or hydrokinetic power will certainly impact and will be impacted by federal and state regulations designed to protect cultural resources. In this environment, proactive measures to understand the nature and distribution of submerged cultural resources, whether they are pre- or post contact, is critical. The difficulties experienced by the Cape Wind development off southeastern Massachusetts is ample warning of the sensitivities and issues that can arise.

In this limited study, we identify some of the tools and protocols that can assist BOEMRE in understanding the scale and scope of cultural resources in any particular area. We address the options for archaeological geophysical survey, suggest a Cultural Landscape Approach as powerful analytical and interpretive tool, and recommend an enhanced form of Archaeological Sensitivity Analysis combined with preliminary Paleo-Archaeological Landscape Reconstruction as protocols for understanding archaeological site distribution and significance.

We recommend the use of a two-tier structure for archaeological and geophysical survey. Tier 1 archaeological surveys would be deigned to assess the scale and scope of archaeological resources in an area as well as identify distribution patterns. These surveys would be conducted as part of broad baseline studies in anticipation of offshore alternative energy development and would include some selective scuba or ROV-based groundtruthing of targets. Tier 1 surveys should dovetail with geophysical survey for benthic habitat analysis and geological studies. Survey strategy should be informed by archaeological survey theory as well as the other tools and protocols proposed in this report, namely the results of the Cultural Landscape Approach and Archaeological Sensitivity Analysis.

In large areas, Tier 1 surveys should be based on a random or stratified sample of transects or blocks. The most efficient instrumentation for these studies are based on acoustics and we recommend either dual-channel, dual frequency side scan sonar and high resolution multibeam or interferometric sonar. In either case, the survey should be sufficient to resolve objects 0.5 m in length. Archaeological and geophysical work should be controlled by a state-of-the-art, survey-grade GPS navigation system and hydrographic software.

Geophysical survey should also include the collection of sub-bottom profiler data, which should be collected at high frequency, and if possible some magnetometer data. The latter should be considered less important for Tier 1 surveys. During post-processing, acoustic features should be identified, listed and prioritized. A categorizing system should be developed that has at least three, and preferably five, levels of potential significance. A representative sample of features identified during survey should be investigated by scuba-equipped archaeologists or ROV.

Tier 2 archaeological surveys would be designed to identify all significant cultural resources in an area and should be centered on Areas of Potential Effect (APE) from offshore development. These surveys are similar to those already required by BOEMRE. BOEMRE and its predecessor the Minerals Management Service have long established, yet continuously evolving, standards for archaeological survey of APE. We reviewed those standards for this report and recommend only a few minor changes. We recommend that BOEMRE require either dual-channel, dual frequency side scan sonar and high resolution multibeam or interferometric sonar surveys. In either case, the survey should be sufficient to resolve objects 0.5 m in length and should cover 100% of the APE. We also recommend that magnetometer data be collected with an instrument capable of 0.5 gamma sensitivity. Other current BOEMRE requirements - including standards for a high-resolution chirp sub-bottom profiler, lane spacing and post-processing - we consider to be entirely appropriate.

We recommend the use of a Cultural Landscape Approach as an overarching framework for understanding, interpreting and assessing cultural resources in any area targeted for offshore renewable energy development. The questions and contexts we suggest provide a good starting point for characterizing cultural heritage resources and are transferable to multiple geographic regions. We recommend that BOEMRE adopt the MPA FAC definitions of cultural heritage.

CLA recognizes that places and cultural heritage resources can have different or multiple meanings and levels of significance based on how people from different cultures, times, or backgrounds have interacted with the landscape. Adopting this pluralistic approach increases the likelihood that cultural heritage resources will be found, recognized, and appropriately respected as decisions are made about the siting and potential effects of offshore alternative energy projects. CLA has many advantages, not least of which is that it provides a structure and place for tribal and indigenous people to developing their own landscape contexts. Although BOEMRE should facilitate this process, participation should be voluntary and the input should be evaluated in its own cultural terms. Where appropriate, a working group of tribal and indigenous representatives and cultural heritage professionals should be commissioned to produce complementary studies of any given area.

CLA bridges traditional historic preservation-based approaches to maritime heritage resource management and the broader consideration and integration of human factors in the environment called for by Ecosystem-based Management, Coastal and Marine Spatial Planning, and the National Ocean Policy.

Our final set of recommendations relate to archaeological site modeling and geospatial analysis. With sufficient information for key sets of environmental variables associated with human behavior, terrestrial archaeologists have, in some places, developed relatively robust predictive models that organize the landscape into zones of probability for the presence of archaeological resources. Although highly useful, such models are place- specific and typically involve considerable expense and years of effort. The time and costs involved make developing true predictive models for underwater cultural resources in anticipation of offshore alternative energy development not practical. We recommend, therefore, the use of enhanced Archaeological Sensitivity Analysis and Preliminary Paleo-Archaeological Landscape Reconstruction.

Paleo-archaeological landscape reconstruction is a critical component of any baseline study for offshore alternative energy assessments. It is particularly important in areas of the continental shelf that have experienced significant sea level rise since the last glacial maximum (LGM). In some areas this can be upwards of 70 meters. These areas of the seafloor possess significant potential for submerged pre-contact archaeological sites.

A preliminary paleo-archaeological reconstruction is achievable as part of baseline offshore alternative energy studies. It requires, however, substantial integration of disciplines and methodologies. Using a combination of geological knowledge, sub-bottom data, side scan sonar data, and coring, it is possible to partially reconstruct the landscape prior to inundation and marine sedimentation. As a result it is possible to identify: areas that were sub-aerially exposed, relic surfaces, glacial lakes, relic riverbeds and the sedimentary regime.

We recommend Archaeological Sensitivity Analysis as a tool for offshore alternative energy baseline studies for submerged cultural resources. ASA can help identify areas with greater likelihood for containing archaeological resources and can help developers and managers assess the time required to address cultural resources issues along with the associated costs and threats to the resources from development. In many cases, ASA relies on the experience of a professional archaeologist to interpret historic, archaeological, GIS, geophysical, and site-specific data so as to assign archaeological sensitivity zones. ASA clearly a valuable tool and has demonstrated its worth. Nevertheless, the application of statistical analysis can inject greater rigor into ASA and create more robust sensitivity zones. As a case study, we used the extensive data sets collected as part of the Rhode Island Ocean SAMP to enhance ASA. We started with 23 variables, subsequently narrowed down to 12, and used linear regression to help explain site historic shipwreck distribution. As a result, we created a probability surface with high, medium and low zones. The high probability zone encompassed 15% of the study area, but contained 56% of the known shipwrecks. While we have not been able to refine our study or test whether the variables used to create the probability surface in Rhode Island waters are transferable to other offshore areas around the United States, the methodology used here provides a promising tool for BOEMRE as the agency looks to understand the implications of offshore renewable energy development on cultural resources.

LIST OF REFERENCES

Agresti, A. 2007. An Introduction to Categorical Data Analysis, 2nd. Ed., Hoboken, NJ: Wiley and Son.

Angelstram, P. 1997. Landscape Analysis as a tool for the scientific management of biodiversity. *Ecological Bulletins*, 46: 140-170.

Banning, E.B. 2002. *Archaeological Survey*, 1st edition. New York: Springer.

Bureau of Ocean Energy Management, Regulation & Enforcement. Nd. Geological and Geophysical (G&G) Technical and Report Guidelines for Physical Characterization Surveys and Archaeological Surveys (draft).

Crowder, L., and E. Norse. Essential ecological insights for marine ecosystem-based management and marine spatial planning. *Marine Policy* 32: 772-778.

Demaris, A. 1992. *Logit modeling: Practical applications*. Newbury Park, CA: Sage.

Dincauze, D. F. 1968. Cremation Cemeteries in Eastern Massachusetts. Papers of the Peabody Museum of Archaeology and Ethnology, 59(1). Peabody Museum, Harvard University, Cambridge, MA.

Dincauze, D. F. 1974. An Introduction to the Archaeology of the Greater Boston Area. *Archaeology of Eastern North America* 2(1): 39–67.

Douvre, F. 2008. The engagement of stakeholders in the marine spatial planning process. *Marine Policy*, 32: 762-771.

Ehler, C. 2008. Conclusions: Benefits, lessons learned, and future challenges of marine spatial planning. *Marine Policy*, 32: 840-843.

Elia, R.J. U.S. Protection of underwater cultural heritage beyond the territorial sea: problems and prospects. *The International Journal of Underwater Archaeology,* 29 (1): 43-56.

Farina, A. The cultural landscape as a model for the integration of ecology and economics. *Bioscience,* 50 (4): 313-320.

Gaines, W. C. 2008. *Encyclopedia of Civil War Shipwrecks*. Louisiana State University.

Keatts, H. and G. Farr. 2002. *The Bell Tolls: Shipwrecks and Lighthouses, Volume 1, Block Island.* Laurel, NY: Main Road Books.

King, T. F. 2008. *Cultural Resource Laws & Practice: An Introductory Guide*. Walnut Creek, CA: AltaMira Press.

Lytle, W. M., compiler. 1952. *Merchant Steam Vessels of the United States 1807 - 1868.* Limited first edition, No. 601 of 1000 copies. Steamship Historical Society of America.

McManamon, F.P. 2000. The Archaeological Resources Protection Act of 1979 (ARPA). Reproduced from Linda Ellis, *Archaeological Method and Theory: An Encyclopedia*. New York: Garland Publishing. http//www.nps.go/archaeology/tools/Laws/arba/htm.

Madrigal, M. D. NOAA's National Marine Sanctuary Resources and Undersea Threats Database: Past, Present and Future. http://www.iosc.org/papers_posters/2008%20183.pdf

Marx, R. F. 1975. *Shipwrecks of the Western Hemisphere, 1492-1825*. D. McKay Co.

Mather, I.R. and G. P. Watts, Jr. 1998. Geographic Information Systems for Cultural Resource Management and Site Specific Investigations. In: *Underwater Archaeology 1998,* edited by Lawrence E. Babits. Tucson, Arizona: Society for Historical Archaeology.

Mather, I.R. and G. P. Watts, Jr. 2002. Geographic Information Systems. In: *International Handbook of Underwater Archaeology,* Carol V. Ruppé and Janet F. Barstad, editors. Plenum Publishing Corporation.

Massachusetts Historical Commission. 1982. Historic and Archaeological Resources of Southeast Massachusetts. Massachusetts Historical Commission, Office of the Secretary of State, Boston, MA.

Minerals Management Service. 1999a. What archaeological reports and surveys must I submit. 30cfr250.194.

Minerals Management Service. 1999b. Subpart B – Exploration and Development and Production Plans. 30cfr250.203.

Minerals Management Service. 2005a. Appendix NO.1. Guidelines for Archaeological Resource Surveys. NTL2005-G07.

Minerals Management Service. 2005b. Notice to Lessees and Operations of Federal Oil and Gas Leases in the Alaska Outer Continental Shelf Region. NTL No. 05-A03.

Minerals Management Service. 2005c. Notice to Lessees and Operators of Federal Oil and Gas Leases and Pipeline Right of Way Holders on the Outer Continental Shelf, Gulf of Mexico OCS Region. NTL No. 2005-G10.

Minerals Management Service. 2006. Notice to Lessees and Operators (NTL) of Federal Oil and Gas Leases and Pipeline Right of Way (ROW) Holders on the Outer Continental Shelf (OCS), Gulf of Mexico OCS Region (GOMR). NTL No. 2006-G07.

Minerals Management Service. 2008. Notice to Lessees and Operators (NTL) of Federal Oil and Gas Leases and Pipeline Right of Way (ROW) Holders on the Outer Continental Shelf (OCS), Gulf of Mexico OCS Region (GOMR). NTL No. 2008-G20.

Minnesota Department of Transportation. 2005. Minnesota Archaeological Predictive Model. Minnesota Department of Transportation, St. Paul. MN. http://www.mnmodel.dot.state.mn.us/index.html

Mulholland, M.T. 1984. *Patterns of Change in Prehistoric Southern New England: A Regional Approach* .Unpublished Ph.D. dissertation, Department of Anthropology, University of Massachusetts, Amherst, MA.

Oxley, I. 2001. Towards the integrated management of Scotland's cultural heritage: examining historic shipwrecks as marine environmental resources. *World Archaeology,* 32 (3): 413-426.

Peng, C., K. Lee, and G. Ingersoll. 2002. An introduction to logistic regression analysis and reporting. *The Journal of Education Research*, 96(1), Sept: 3-14.

Pomeroy, R., and F. Douvre. 2008. The engagement of stakeholders in the marine spatial planning process. *Marine Policy*, 32: 816-822.

Quinn, W. P. 1973. *Shipwrecks Around Cape Cod*. Lower Cape Pub Co.

Rhode Island Coastal Resources Management Council. 2010. Rhode Island Special Area Management Plan, Vols. I and II. Providence, RI.

Rhode Island Coastal Resources Management Council. Vol. I. Chapter 4. 2010. Cultural and Historic Resources in Rhode Island Ocean Special Area Management Plan. Providence, RI. pp. 238-326.

Rhode Island Historic Preservation and Heritage Commission. 1982. A Management Plan for Prehistoric Archaeological Resources in Rhode Island's Coastal Zones. 2 vols. Rhode Island Historical Preservation Commission, Providence, RI.

Rhode Island Historic Preservation and Heritage Commission. 1986. The Rhode Island Historical Preservation Plan . Rhode Island Historical Preservation Commission, Providence, RI.

SAS Institute, 1999. SAS/STAT® User's Guide, Version 8, Ch. 39. SAS Institute Inc., Cary, NC.

Shomette, D. G. 2007a. *Shipwrecks on the Chesapeake: Maritime Disasters on Chesapeake Bay and Its Tributaries, 1608- 1978*. Tidewater Publishers.

Shomette, D. G. 2007b. *Shipwrecks, Sea Raiders, and Maritime Disasters Along the Delmarva Coast, 1632-2004*. 1st edition. The Johns Hopkins University Press.

Singer, S. D. 1998. *Shipwrecks of Florida: A Comprehensive Listing*. 2nd edition Pineapple Press.

Smith, H. D. and A. D. Couper. 2003. The management of the underwater cultural heritage. *Journal of Cultural Heritage,*. 4: 25-33.

Snyder, M. and D. Snyder. 1998. *Rhode Island Adventure Diving*. Westfield: Marlene and Don Snyder.

Snyder, M. and D. Snyder. 1999. *Rhode Island Adventure Diving II*. Westfield: Marlene and Don Snyder.

St. Martin, K., and M. Hall-Arber. 2008. The missing layer: Geo-technologies, communities, and implications for marine spatial planning. *Marine Policy*, 32: 779-786.

Stick, D. 1985. *Graveyard of the Atlantic: Shipwrecks of the North Carolina Coast*. The University of North Carolina Press.

Thorbahn, P. F. 1982. The Prehistoric Settlement Systems of Southern New England: Final Report of The Interstate 495 Archaeological Data Recovery Program, Vol. I. Public Archaeology Laboratory, Department of Anthropology, Brown University Report. Submitted to the Massachusetts Department of Public Works, Boston, MA.

U.S. Coast Guard Navigation Center. NAVCEN MS 7310, Alexandria, VA 20598.

Watts, Jr., G.P., and I.R. Mather. 1996. GIS for Historical and Cultural Resource Management in the Waters around Charleston. Data sets and report submitted to the City of Charleston, South Carolina.

Watts, Jr., G.P., and I.R. Mather. 1997. Historic Properties Treatment Plan and Geographic Information System for the James River Navigation Project." Data sets and report submitted to US Corps of Engineers, Norfolk District, Virginia.

Westerdahl, C. 2003. The maritime landscape. *The International Journal of Nautical Archaeology,* 21(2): 5-14.

Wilson, C. and P. Groth, Eds. 2003. *Everyday America: Cultural Landscape Studies after J.B. Jackson.* Berkeley, CA: University of California Press.

Zander, C. M. and O. Varmer. 1996. Closing the Gaps. Common Ground vol. 1 (3/4). National Parks Service, Washington D.C.

TASK 1.5

STANDARDIZED PROTOCOLS FOR ASSESSING THE EFFECTS OF OFFSHORE ALTERNATIVE ENERGY DEVELOPMENT ON CULTURAL RESOURCES

This report delivers the results for Standardized Protocols, Monitoring Systems, and Test Results (Deliverable #5)—for National Oceanographic Partnership Program project number M10PC00097, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This document presents the results of an effort directed at establishing standardized monitoring protocols for monitoring the effects of offshore renewable energy (ORE) developments. The objectives of this project task and report are to:

- Present the standardized protocols and monitoring systems, specifically to address effects on benthic habitat and resources, fisheries resources, fishing activity, marine mammals and sea turtles, and marine birds, that have been developed using the best scientific methodologies and approaches to ensure valid data collection;
- Describe clear methods and metrics that are flexible enough to be applicable to a wide variety of sites, environmental conditions, and energy-generating technologies, and that also incorporate adaptive mechanisms to respond to changes in technologies, environmental conditions, and/or data needs;
- Present lessons learned from testing these protocols and monitoring systems on results of the Rhode Island Ocean Special Area Management Plan (Ocean SAMP) monitoring and evaluation initiative: the Technology Development Index (TDI), the Ecological Value Index (EVI), and the Cumulative Use Evaluation Model (CUEM).

TASK 1.5

DEVELOPING STANDARDIZED PROTOCOLS AND MONITORING

Contributing Authors:

Michelle Carnevale, URI Coastal Resources Center
Robert Kenney, URI Graduate School of Oceanography
Peter Paton, URI College of Environmental and Life Sciences
Malia Schwartz, URI Graduate School of Oceanography
Emily Shumchenia, URI Graduate School of Oceanography
Sarah Smith, URI Coastal Resources Center
Kristopher Winiarski, URI College of Environmental and Life Sciences

EXECUTIVE SUMMARY

This report delivers the results for Standardized Protocols, Monitoring Systems, and Test Results (Deliverable #5)—for National Oceanographic Partnership Program project number M10PC00097, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. This document presents the results of an effort directed at establishing standardized monitoring protocols for monitoring the effects of offshore renewable energy (ORE) developments. The objectives of this project task and report are to:

- Present the standardized protocols and monitoring systems, specifically to address effects on benthic habitat and resources, fisheries resources, fishing activity, marine mammals and sea turtles, and marine birds, that have been developed using the best scientific methodologies and approaches to ensure valid data collection;
- Describe clear methods and metrics that are flexible enough to be applicable to a wide variety of sites, environmental conditions, and energy-generating technologies, and that also incorporate adaptive mechanisms to respond to changes in technologies, environmental conditions, and/or data needs;
- Present lessons learned from testing these protocols and monitoring systems on results of the Rhode Island Ocean Special Area Management Plan (Ocean SAMP) monitoring and evaluation initiative: the Technology Development Index (TDI), the Ecological Value Index (EVI), and the Cumulative Use Evaluation Model (CUEM).

This report serves as a guide to both developers and regulators for determining the most appropriate monitoring protocols for a given ORE project and technology type. We designed monitoring protocols to answer existing questions about the potential effects of ORE projects on environmental resources and about the most appropriate way to monitor these effects. Our monitoring protocols are also standardized among development types, so that data are being collected in a consistent manner across studies. The monitoring protocols that we developed are presented as a menu of options, not as a to-do list for developers. Furthermore, this report is not intended to supplant existing federal or state authority to determine what studies should be conducted or what monitoring should be required in order to issue a permit for any form of ORE developments.

Development of Monitoring Protocols

The monitoring protocols described within this report are based on indicators of the likely changes to the ecosystem due to ORE developments (summarized in Task 1.2 Report). These protocols are based on our analysis of which effects are most important for monitoring given their likelihood, level of certainty, and potential for affecting the resource, activity, or community. We used the word "certainty" to refer to the amount of evidence available from studies conducted on a particular effect. High certainty indicates that there was a large body of literature documenting or studying an impact. It is important to note that "certainty" does not refer to the chance that an impact will occur. The chance of an impact occurring is more appropriately described as likelihood, a concept that was not addressed in this study. Therefore, where we describe an effect with a high certainty of major impact, this can be interpreted as "if the named effect occurs, then the magnitude of the impact on environment will be major."

We proposed an indicator of each effect to serve as a proxy for the condition of the resource as a whole and created an adaptive monitoring framework that incorporates the use of these indicators to track change. In order to ensure that each ecosystem component and the unique issues within each component were given adequate attention in any monitoring strategy, we implemented a hierarchical decision-tree framework. We developed two types of decision trees. The first decision tree—the "**Effects Decision Tree**"— determines the approximate magnitude of effects from ORE development on each ecosystem component considering three factors—energy type, foundation type, and development scale. The second type—"**Component Decision Trees**"— is a suite of finer-scale decision trees for each of the ecosystem components that determine which monitoring protocols are recommended given a more specific suite of characteristics related to the development type (e.g., stage of development). The Effects Decision Tree takes 39 possible scenarios that result from various combinations of the three development factors and reduces them to **six** main Effects Scenarios (E1 – E6). Once the user has determined which ecosystem components and associated effects are of concern for the development under examination, they use the Component Decision Trees to find appropriate protocols. The Component Decision Trees take these component-specific concerns into consideration and terminate with a manageable number of recommended monitoring protocols.

In total, 31 monitoring protocols were developed, which include twelve to monitor avian species, nine to monitor marine mammals and sea turtles, six to monitor fish or fishing activity, and four to monitor the benthic habitat and resources. Each of these protocols is tied to one or more indicators of a potential effect. The intent is not for regulators or developers to use all of these protocols, but to use the decision trees and the protocols to determine the best practices for monitoring effects deemed of concern for a particular project or region. Additionally, several Effects Scenarios were developed to summarize the suite of potential effects that may result from different ORE technology types and to highlight which of those effects are considered to be major or moderate at the scale of a commercial wind farm. These scenarios are intended to assist regulators or developers in determining which effects will be most critical to monitor**.**

PROJECT SCALE

Demonstration-scale projects provide an opportunity for research to reduce some of the existing uncertainty around the potential environmental effects of ORE projects, assisting regulators in prioritizing monitoring needs and making better decisions. We recommend that the monitoring requirements for demonstration-scale projects be adaptive. Where there are few or no commercial-scale facilities available for monitoring, as many studies, as is feasible, should be conducted at demonstration-scale sites that examine effects of concern for similar commercial-scale project.

APPLYING THE PROTOCOLS AND DECISION TREES

The project team was also tasked with testing the protocols by applying them to the SAMP, and considering how the additional data collected through these monitoring protocols might affect site-evaluation tools developed by the project team including the Technology Development Index (TDI) and the Ecological Valuation Index (EVI) and Cumulative Impact

Model-Ecological (CIM-Eco). The protocols did not result in any changes to the TDI or EVI/CIM-Eco. However, having standardized methods for collecting baseline and impact data across projects will allow the data to be compiled more easily and incorporated into these models. While baseline data collected for a particular project will likely only cover a project site, adding this information to the model framework may inform future siting. For example, if monitoring studies conducted at demonstration-scale projects indicate that EMF impacts are negligible, the CIM-Eco score can be adjusted to reduce the weighting of EMF impacts in the analysis.

Two case studies are presented, testing the decision tree framework and monitoring protocols for the Block Island Wind Farm in state waters and the Massachusetts and Rhode Island Wind Energy Area in federal waters, both located within the Rhode Island SAMP study area. The test cases found that the framework was successful in selecting a range of appropriate protocols to test potential effects for these two examples. Some knowledge of the local environment including the target species for testing is helpful in choosing monitoring protocols. For the demonstration-scale test case in particular, the list of monitoring protocols provided is longer than the number that would likely be conducted; however, it provides regulators and decision makers with a starting point that is based on the best available science.

Conclusions and Recommendations

The monitoring framework, protocols and the decision trees developed for this project represent an important first step in standardizing monitoring for ORE projects in the United States. The data collected through a standardized monitoring program will provide a means for refining our understanding of the potential effects of ORE projects, and will allow for better siting decisions. By implementing our framework and a comprehensive monitoring program at each new ORE development and by comparing and aggregating data, much of the existing uncertainty surrounding potential adverse effects will be reduced. One of the lessons learned in this project is the importance of a monitoring program that is adaptive to both regulatory needs and local concerns. In drafting a set of protocols we attempted to account for variability in regions, target species, etc., but decisions about the most appropriate ways to monitor an ORE development will still have to be made on a case-by-case basis. It is our hope that our framework and monitoring protocols will prove useful to regulators and facilitate the permitting process.

TASK 1.5

DEVELOPING STANDARDIZED PROTOCOLS AND MONITORING

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This report serves as one of the Year 2 deliverables—Draft Final Results: Standardized Protocols, Monitoring Systems, and Test Results (Deliverable #5)—for the National Oceanographic Partnership Program project number M10PC00097, *Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship*. This document presents standardized protocols for monitoring the effects of offshore renewable energy (ORE) developments. The objectives of this part of the project were to:

1. Present the standardized protocols and monitoring systems, specifically to address effects on benthic habitat and resources, fisheries resources, fishing activity, marine mammals and sea turtles, and marine birds, that have been developed using the best scientific methodologies and approaches to ensure valid data collection;
2. Describe clear methods and metrics that are flexible enough to be applicable to a wide variety of sites, environmental conditions, and energy-generating technologies, and that also incorporate adaptive mechanisms to respond to changes in technologies, environmental conditions, and/or data needs;
3. Present lessons learned from testing these protocols and monitoring systems on results of the Rhode Island Ocean Special Area Management Plan (Ocean SAMP) monitoring and evaluation initiative: the Technology Development Index (TDI), the Ecological Value Index (EVI) and the Cumulative Use Evaluation Model (CUEM)

The development of standardized monitoring protocols that can be applied to various types of ORE projects throughout the United States would represent a major step toward streamlining the permitting process. Establishing a set of standardized monitoring protocols is also important to developing a broader understanding of the effects of ORE developments on various components of the marine ecosystem. Although not a requirement of the contract, we developed a series of decision trees to assist a user in selecting the most appropriate methods for monitoring various potential effects to ensure our products were as useful as possible to decision makers and developers.

ORE development is here defined as the construction and operation of one or more devices designed to harness power from the marine environment (wind, tidal, and wave power considered here), and includes any necessary infrastructure, subsea cables, the vessels necessary to construct or install an ORE project, and the footprint of a project. The descriptions and thresholds for effect levels were derived from the definitions used in the PEIS (MMS 2007): minor—should not influence or have only small effects on the resource, activity, or community; moderate—effects could moderately influence the resource, activity, or community, generally or for particular species; major—effects could considerably influence the resource, activity, or community, generally or for particular species. Inland and coastal effects resulting from the construction or manufacturing of ORE were not considered in this study. We examined the effects of ORE projects on benthic habitat and resources, marine mammals, sea turtles, fish, and avian species. We also considered effects on one human use—fishing activity—because of the inextricability of the effects on fishing activity from effects on fish themselves, and the resulting concerns of fishermen about potential effects on their livelihood. As part of the full project, our team also considered the potential effects on cultural resources (see Task 1.4 Report). While there is need for evaluating the potential for other effects from ORE, going beyond those topics mentioned above was not part of the scope of this project. For example, we do not explore the possible effects resulting from multiple synergistic human uses of ORE development, such as aquaculture.

At present, the effects of ORE developments on the environment are not well understood, and any conclusive data on effects are limited (Gill 2005; Inger et al., 2009; Boehlert and Gill 2010). Existing data from studies on effects have resulted primarily from projects in Europe, where ORE development began several years ago. The extent of monitoring conducted and the amount of data resulting from these projects varies. Most of these developments have not been in operation for a sufficient length of time or have collected enough data to conclusively determine whether effects have resulted. We conducted a literature review and analysis of potential effects (see Task 1.2 Report). This analysis concluded that no new effects have been identified beyond what was described in the PEIS (MMS 2007) and that a great deal of uncertainty still exists as to the likelihood and magnitude of most potential effects.

Because of differences between Europe and the U.S. in terms of regulatory requirements, environmental settings, and species present at development sites (Stelzenmüller et al., 2012), there is a considerable need for U.S.-specific guidance to ensure thorough data collection as ORE projects develop to evaluate effects and assess potential effects. Standardized protocols improve impact assessment by following a single methodology at multiple sites, permitting comparison and aggregation of data (OSPAR 2002). Building a uniform database of environmental effects will allow us to better refine our understanding of drivers and stressors acting at ORE sites, improve the Environmental Impact Statement (EIS) process, and refine monitoring requirements in the future as certain effects are suggested to be either negligible or worthy of concern. This knowledge can be used to encourage development in areas where known effects are expected to be minimal. In addition, reducing the existing uncertainty about environmental effects related to ORE will likely ease public concern about development and therefore improve the siting process.

Monitoring an effect or an effect means that the monitoring protocol must be designed to measure change against some baseline condition or management objective (Link 2005; Samhouri et al., 2011). This change may be measured temporally, as in between seasons or years, before and after construction, or spatially, including measuring differences between an affected and a control area. Designing a study that can both provide conclusive evidence of an effect (or lack thereof) and separate this effect from the noise of seasonal or interannual environmental variability can be problematic (Carey and Keough 2002). Furthermore, not all of the potential effects will be directly observable. For example, observations of underwater ORE structures will not likely be continuous. Therefore, in order to determine if a foundation has an effect on seabed structure, for example, discrete measurements of seabed volume will be made and compared through time. In this example, measured changes in seabed volume serve as a representative of the effect of the foundation on the seabed, and in this way is considered to be an indicator of that effect. In general, indicators can be used as a means to quantitatively track change in the context of ecosystem-based management goals (Leslie and McLeod 2007; Muxika et al., 2007; Rees et al., 2008). Developing indicators of change at ORE sites would be immensely helpful to impact assessments and, if developed across disciplines (e.g., biology, geology, physical oceanography), enable an overall assessment of the condition of the ecosystem.

We designed protocols to help keep development costs from becoming prohibitive. In most cases, the costs for monitoring will be borne by the developer of the renewable energy project, and so it is important that monitoring does not serve as a barrier to development. Thus our protocols are intended to be reasonable and not overly burdensome. In some cases we provide multiple options for monitoring at varying cost levels to offer alternatives depending on the intensity of the monitoring desired by the developer and/or regulator.

1.1. How This Report is Intended to be Used

This report is meant as a guide to both developers and regulators to determine the most appropriate monitoring protocols for a given ORE project and technology type, including the cables used to connect devices to each other and to the shore. The intended outcome of the monitoring is an understanding for the potential effects of the device, as well as those of device construction and decommissioning.

This report is not intended to supplant existing federal or state authority to determine what studies should be conducted or what monitoring should be required in order to issue a permit for any form of ORE development. The requisite Environmental Assessment or EIS as part of the National Environmental Policy Act process must be approved by the respective federal and state agencies involved in permitting, as they have the ultimate determination of whether any proposed monitoring is acceptable. Decisions on what type of monitoring should be conducted and how it is conducted will still need to be made on a site-specific basis. This will ensure that monitoring addresses 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 protocols presented, along with the accompanying decision trees, are intended to support this decision-making.

1.2. Site Selection

We do not intend for these monitoring protocols to be applied without an overarching consideration of site selection for ORE development. We designed these protocols with the assumption that some form of marine spatial planning process is in place to select the best locations for development based on maximizing the energy produced, minimizing development and production costs, reducing user conflicts, and minimizing the known potential for environmental and socio-economic impacts. The site-selection process assumes that some of this information is known and incorporated into the regulatory and leasing process. In all likelihood, site selection will be done largely with existing data. However, some of these protocols could be scaled up to collect data on this larger scale. Those protocols that address questions of abundance and distribution (marine mammal/sea turtles, avian species, fisheries resources, benthic habitat and resources) could be employed on a regional or sub-regional scale to evaluate resources as part of a site-selection process. If site-selection data are collected with standardized protocols and at the appropriate scale, the resulting data may also be useful as site-specific baseline data that can be compared to the data collected during the monitoring program.

The Siting Evaluation Model (SEM) framework developed as part of this project (see Task 2.3 Report) is intended to assist with the site-selection process and cumulative impact evaluation of ORE developments. The SEM framework considers ecological value, socio-economic (human) uses, and technological development.

1.3. AREAS FOR ADDITIONAL RESEARCH

Additional studies, including both *in situ* and laboratory-based research, are needed to better understand the drivers of particular effects. Understanding the drivers will improve our ability to detect effects and increase the efficiency of monitoring programs. Monitoring studies are designed to detect effects, but they may not identify the driver or combination of drivers of those effects. Changes to distribution or abundance of various species on different spatial scales may occur due to multiple drivers (e.g., operation noise and EMF). Studies on the drivers of negative effects should be ongoing and occur alongside other monitoring efforts. In many cases this may be unreasonable to require of a developer.

1.4. PROJECT ADVISORY COMMITTEE

We developed the monitoring protocols and decision trees with the assistance of our Project Advisory Committee (PAC), made up of experts including academics, regulators, and industry representatives (Appendix C). These products were developed through a process that included document sharing and project meetings with the full committee as well as with subgroups of the PAC. By engaging the PAC in this project and vetting our products through this group of regulators, researchers, and industry, we were able to develop more thorough and realistic tools that are satisfactory to each of these groups.

2. USING A COMMON LANGUAGE – CMECS

The U.S. Coastal and Marine Ecological Classification Standard (CMECS) was chosen to provide a guiding framework for developing monitoring protocols for several reasons (Allee et al. 2012). First, consistency in nomenclature is particularly important for describing reference states and ecosystem changes and will ensure uniformity when dealing with various assessments. Second, CMECS is particularly suited to environmental assessments because of the explicit acknowledgement of ecological features' spatial extent, temporal persistence, and relationships with other natural and human features. The effects of ORE developments have been described in a spatial-temporal context elsewhere (Wilhemsson et al. 2010). These effects are translatable to the CMECS space-time framework and can be overlaid with the relevant CMECS components that may capture particular effects. Lastly, the CMECS structure envelops interdisciplinary marine-science data in an integrated way, with linkages between data types being a major focus. Therefore, by using CMECS as the guiding framework for these applications, an ecosystem-based approach is encouraged.

We developed the monitoring protocols to produce data in a language conforming to that used by CMECS. While CMECS is a standard developed for the purposes of classifying marine habitat types, this standard provides a common language for marine environmental data, and characterizes marine environmental resources in space and time. Only the benthic habitat and resources monitoring protocols refer directly to the CMECS language. We found the CMECS framework to be a useful way of talking about environmental change, but it is currently most relevant to our discussions of the benthic habitat and resources. The other protocols were designed with the CMECS spatial-temporal framework in mind.

3. MONITORING OBJECTIVES AND INDICATORS

The monitoring protocols described within this report are based on indicators of the likely changes to the ecosystem due to ORE developments (summarized in Task 1.2 Report) (Table 1). It would be impractical to monitor every interaction that could potentially result in an effect to an organism or abiotic component of the ecosystem; thus these protocols are based on our analysis of which effects are most important for monitoring given their likelihood, level of certainty, and potential for affecting the resource, activity, or community. The effects presented below are those chosen as most important based on a literature review and on expert opinion. Here, we used the word "certainty" to refer to the amount of evidence available from studies conducted on a particular effect (see Task 1.2 Report). High certainty indicates that there was a large body of literature documenting or studying an effect. Medium certainty indicates some documentation or anecdotal evidence is available but there is no clear consensus among experts within the literature. When there is limited or no documentation or anecdotal evidence available for a particular effect, we assign these effects as having low certainty. It is important to note that "certainty" does not refer to the chance that an effect will occur. The chance of an effect occurring is more appropriately described as likelihood, a concept that was not addressed in this study. Therefore, where we describe an effect with a high certainty of major impact, this can be interpreted as "if the named effect occurs, then the magnitude of the impact on environment will be major."

We propose an indicator of each effect to serve as a proxy for the condition of the resource as a whole (Table 1). For example, we use a change in the abundance, distribution, or behavior of a species or group of species to indicate that an effect is taking place. It may not always be possible to identify a driver or drivers of the effect. Because of our limited understanding of driver-effect relationships at ORE developments, the priority at this initial stage is to first determine whether or not a resource is being affected.

In order to determine whether or not a resource is being affected, we seek to track changes in the indicators. We have developed monitoring protocols that employ a number of tools and statistical methods to detect change. The effectiveness of many of these tools is discussed in the Task 1.3 Report, and the effectiveness of various statistical methodologies is largely dependent on the sample size attained for a given study (Carey and Keough 2002; see Task 1.3 Report). Many of our monitoring protocols recommend appropriate sample sizes that were estimated given some stated assumptions about the spatial size of the study area. To maximize the chances that any of our monitoring protocols actually detect changes at a particular ORE project, a statistician or ecologist should be consulted to ensure that sample sizes are appropriate for that particular study area.

It is very important to remember that minor effects are not necessarily more difficult to detect than major effects. Likewise, "small-scale changes" are not necessarily more difficult to detect than "broad-scale changes" to indicators. For example, the physical disturbance to the seabed due to gravity-base foundation installation is classified as minor at the demonstration-scale. This effect is classified as minor because the spatial extent is very small and duration of effect is very short; however, this disturbance is very easily detectable with well-placed sediment grain size or underwater videography samples taken before and after installation. The sensitivity of the tools/instruments making the measurements, along with the robustness of a statistical sampling plan will influence our ability to detect changes in indicators. Our monitoring protocols were designed with this information in mind, and within those protocols we make recommendations based on the best scientific knowledge of the effects, indicators and unique environmental characteristics associated with ORE developments.

Table 1

Potential environmental effects of ORE development and associated indicators for each ecosystem component.

Topic Area	Effect/Monitoring Objective	Indicator
Benthic Habitat and Resources	Changes to seafloor morphology and structure (compared to pre-construction)	Increase or decrease in seabed volume
	Changes in median grain size, or organic content	Deposition: decrease in median grain size; increase in organic content; increase in seabed volume Scour: increase in median grain size; decrease in organic content; decrease in seabed volume
	Turbidity during construction/decommissioning	Change in water column turbidity
	Change in target species abundance and distribution (e.g, species of importance)	Change in abundance, diversity, % cover, multivariate community composition
	Current speed/direction inside and outside farm	Change in residual flow rates
	Reef effects; colonization on foundations	Increase in % cover, biomass of epifaunal organisms; increase in presence of non-native species;
	Change in density, diversity, dominance structure of infauna	Change in abundance, diversity, % cover, multivariate community composition
Fish	Reef or aggregation effects	Increase in fish abundance around devices; shift in species composition; increase in presence of non-native species
	Changes to abundance/distribution caused by disturbance or habitat alteration	Increase or decrease in fish abundance; increase or decrease in target species; shift in species composition; change in density, diversity, and dominance structure of fish species; increase in presence of non-native species
	Blade strikes / pressure gradients (tidal power)	Observation of blade strike incidents
	EMF effects	Not feasible to monitor directly- changes in fish abundance, behavior, or species composition are indicators
	Installation or Operational noise effects	Not feasible to monitor directly- changes in fish abundance, behavior, or species composition are indicators
Fisheries	Catchability (catch per unit effort) during construction	Catch per unit effort increases or decreases for target species
	Catchability (catch per unit effort) during operation	Catch per unit effort increases or decreases for target species
	Loss of access to grounds	Changes in numbers of vessels fishing near or inside of the renewable energy area; change in the presence of fixed fishing gear inside of or around a renewable energy installation

	Changes in species distribution	Shift in species composition; increase in presence of non-native species
	Reef effects (aggregation)	Increase in fish abundance around devices; shift in species composition; increase in presence of non-native species
Avian Species	Displacement/ attraction	Changes in distribution, abundance, or behavior
	Barrier effects – effects on foraging, roosting, migratory movements	Animals alter migration or commuting flight paths
	Collision mortality	Birds documented striking infrastructure resulting in death or injury
Marine Mammals and Sea Turtles	Vessel strikes	Detection of dead or injured animals
	Noise generated during construction	Detection of dead or injured animals; changes in distribution, abundance, or behavior
	Disturbance or injury during all stages of development, including from vessels	Detection of dead or injured animals; changes in distribution, abundance, or behavior
	Noise generated during operation	Changes in distribution, abundance, or behavior

4. ADAPTIVE MONITORING STRATEGIES

We developed an adaptive and reactive monitoring framework that incorporates the use of environmental indicators to track change (Figure 1). Currently, we have the ability to characterize a baseline condition and assign reference directions to indicators, e.g., increases in sediment grain size at every turbine should accelerate monitoring for scour. Reference directions are useful when data are insufficient to establish more quantitative reference levels, but they only provide an indication of a trend, and do not specify when a threshold of irreversible harm has been reached (Samhouri et al., 2011). In an adaptive monitoring framework, data are synthesized to produce more quantitative metrics and thresholds for environmental indicators of ORE development effects. In a reactive monitoring framework, evidence of an effect should be used to accelerate study of that effect, perhaps by multiple methodologies (refer to Figure 1). Suites of indicators would not only provide a clearer path for goal-setting for developers, but would encourage regulatory monitoring protocols to contribute to our general understanding of the natural variation of marine ecosystems and how human activities can be integrated and harmonized.

Our review of the current state of knowledge regarding the effects of ORE developments and consultation with topic-area experts has provided a solid starting point for proposing indicators of these effects. Building support for an indicator as a representative of an ecosystem attribute or function is an iterative process that can be conducted as monitoring data are collected at ORE sites. At first, where few data exist, qualitative "reference directions" can be used to track change (Samhouri et al., 2011). As a database is built, changes can be quantified and thresholds can be identified relative to effects at particular developments. In rare cases where the natural variability of a parameter has already been characterized, statistical tools may be used to determine appropriate thresholds or even the sampling protocols themselves (e.g., power analyses [Lapeña et al., 2010; Lapeña et al., 2011a; Lapeña et al., 2011b]). In most cases, however, very little is known about natural variability and environmental monitoring efforts will be measuring natural change commingled with the effects of ORE developments. A monitoring framework that considers all of these concerns is essential.

To address these concerns, an adaptive, rather than a static monitoring framework for ORE developments is most appropriate. Firstly, there are many points of weakness in the general understanding of the effects of ORE projects on marine resources that could greatly change monitoring needs and/or requirements. For example, the likelihood and magnitude of indirect effects (e.g., alteration to food webs) and wholly unanticipated effects are unknown (Boehlert and Gill 2010). Data regarding these points may only become available at a later stage of ORE maturity, but current monitoring protocols and regulations should be prepared in anticipation of these types of effects. Next is the current understanding of linkages between effects and indicators. We can agree conceptually that certain environmental/biological parameters are indicative of an ecosystem change, but in many cases we have no estimate of thresholds of concern for these parameters (e.g., how much of a reduction can occur in a bird population before mitigation needs to take place?). Just as experience in ecosystem-based fisheries management has helped propose appropriate thresholds for indicators of fisheries status (Link 2005), experience in managing ORE projects will help clarify the assumptions made between effects and indicators. An adaptive framework is also essential in a field where new technologies are developing and emerging at a rapid pace.

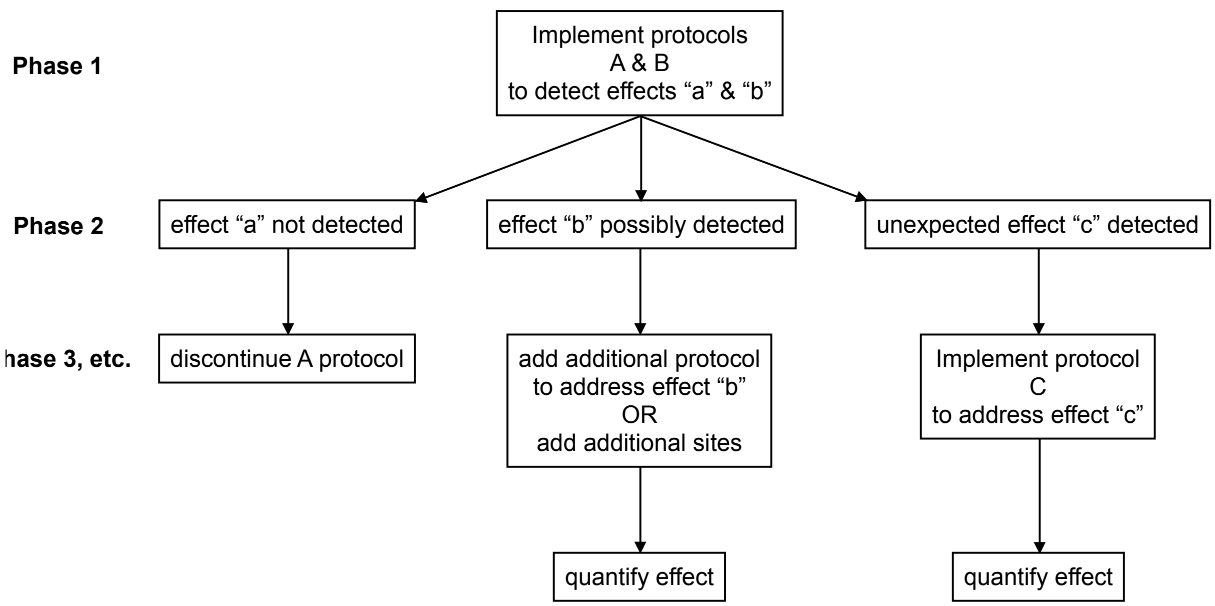


Figure 1. An example of an adaptive and reactive monitoring framework. Each column of the flow chart shows a possible scenario of how monitoring plans could change based on incoming data.

5. EXISTING MONITORING/BASELINE DATA

We developed monitoring protocols with the assumption that there are no or insufficient existing data on the relevant species to establish reference levels prior to monitoring. In some cases, the data may exist but not at a scale appropriate for integration into monitoring efforts. However, in some cases baseline data will exist that can and should be incorporated into monitoring efforts. As described above, we assign reference directions to indicators when we have insufficient data to compare how a change might be related to population levels or to a particular threshold. We designed the monitoring protocols to be flexible and incorporate existing data for better estimates of particular reference points. Where there is an ongoing environmental monitoring program in the project area, and if the methods in use are sufficient to detect a change due to development, data collection should continue using the same methodology for comparable data with a longer period of baseline data.

Commercial and recreational fisheries under federal or state management are a likely resource for baseline data, as surveys are made on a regular basis to provide stock assessments. However, these data for the most part are collected over a large spatial scale to provide stock- or species-wide assessments, and may not be useful for monitoring changes on a smaller scale.

Baseline data are also likely to exist for species that are federally listed as Threatened or Endangered under the Endangered Species Act of 1973 and/or protected under the Marine Mammal Protection Act (MMPA). Many of these species are already being monitored as part of a recovery plan and their population levels may be relatively well understood. Regular assessment of all marine mammal populations within U.S. jurisdiction is required under an amendment to the MMPA enacted in 1994, and annual Stock Assessment Reports are published for the Atlantic and Gulf of Mexico (Waring et al., 2010), Pacific (Carretta et al., 2011), and Alaska (Allen and Angliss, 2011). Monitoring data collected for threatened, endangered, or other protected species could be compared directly to existing reference levels and recovery plan targets. Whereas monitoring for protected species may be ongoing and under the purview of the National Marine Fisheries Service and the U.S. Fish and Wildlife Service, our protocols can be used to conduct additional monitoring. Adverse effects on protected species from ORE development activities could trigger immediate federal regulatory response/mitigation measures. However, we acknowledge that development is likely to be steered away from an area that is essential for any life stage of these species or where such development is likely to put the recovery of these species at risk.

6. DEMONSTRATION-SCALE PROJECTS

Demonstration-scale projects provide an opportunity for research to reduce some of the existing uncertainty around the potential environmental effects of ORE projects, assisting regulators in prioritizing monitoring needs and making better decisions. Due to their size, individual demonstration-scale projects should be considered separately from commercial-scale projects in the extent to which monitoring should be required. Demonstration-scale projects are not expected to result in environmental effects of the same magnitudes as commercial projects for any of the renewable energy device types. However, monitoring protocols implemented at the demonstration-scale will be cheaper due to the smaller spatial footprint of these developments, perhaps enabling a wider variety of protocols to be tested. Greater monitoring effort at these early stages may later reduce monitoring requirements at commercial-scale facilities, as effects are better understood. We recommend that the monitoring requirements for demonstration-scale projects be adaptive. Where there are few or no commercial-scale facilities available for monitoring, studies should be conducted at demonstration-scale sites that examine effects of concern for similar commercial-scale project. As effects are better characterized and methodologies are made more efficient, individual monitoring activities could be phased down in order to maximize the suite of monitoring activities at each development. Overall, we recommend that as many monitoring protocols are implemented as is feasible for the early stages of ORE development in the U.S. We recognize that effort towards monitoring and environmental studies of these developments will be balanced by effort toward technological development and progress.

7. DECISION TREES

In order to ensure that each ecosystem component and the unique issues within each component were given adequate attention in any monitoring strategy, we implemented a hierarchical decision-tree framework. Decision Trees, as decision-support tools, are easy to follow and can help users evaluate alternatives and the impacts of development preferences. Furthermore, the information supplied by the Decision Trees can help manager and regulators prioritize monitoring based on an effect's magnitude and their perceived likelihood of that effect. **Importantly, the use of these decision trees is advised only after a formal marine spatial planning or scoping process has taken place (i.e., existing baseline data have been assembled and evaluated, and conflicting uses among other marine sectors have been resolved).**

We developed two types of decision trees. The first decision tree—the "**Effects Decision Tree**"— determines the approximate magnitude of effects from ORE development on each ecosystem component considering three factors—energy type, foundation type, and development scale. The second type—"**Component Decision Trees**"— is a suite of finer-scale decision trees for each of the ecosystem components that determine which monitoring protocols are recommended given a more specific suite of characteristics related to the development type (e.g., stage of development). We took this approach because each ecosystem component experiences different levels of effect due to different drivers. For example, different foundation types could differentiate several types of effect for benthic habitat and resources, but are not likely to do the same for avian species.

Following a key format, the user answers a series of questions about the development project and is guided through the Effects Decision Tree and toward an eventual "answer" based on the responses to the questions. For the Effects Decision Tree, the "answer" is an Effects Scenario and an associated list of the ecosystem components that may experience major and moderate negative (i.e., adverse) effects from ORE developments, a short description of the type of effects, and an estimate of the certainty regarding these effects. For each Effects Scenario, the lists of major negative potential effects were ranked by proportion and magnitude of total effects so that #1 reflects the component with the most negative effects. To provide more detail on potential adverse effects, all moderate effects and levels of certainty are also provided for each scenario. The lists of moderate effects are not prioritized or ranked and are listed as they appeared in the Renewable Energy Effects Matrix (see Task 1.2 Report).

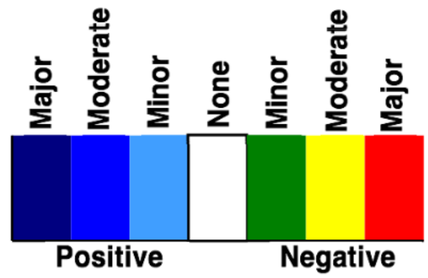
For the Component Decision Trees, the "answer" is a list of monitoring protocols. At this stage, we have combined the protocols for fisheries resources and fishing activity into a single Component Decision Tree, as the protocols created can address indicators for both. Similarly, we have separate Component Decision Trees for marine mammals and sea turtles, but one set of monitoring protocols, as in many cases a single protocol can be used to monitor both components.

7.1. USING THE DECISION TREES

The Effects Decision Tree takes 39 possible scenarios that result from various combinations of the three development factors and reduces them to **six** main Effects Scenarios (E1 – E6). Once the user has determined which ecosystem components and associated effects are of concern for the development under examination, they use the Component Decision Trees to find appropriate protocols. The Component Decision Trees take these component-specific concerns into consideration and terminate with a manageable number of recommended monitoring protocols. For example, the Component Decision Tree for Benthic Habitat and Resources describes 24 total monitoring scenarios, but condenses them into a maximum of four monitoring protocols. Each Component Decision Tree points the user to a series of protocol names and numbers; these are the protocols that should be selected from for monitoring given the particular technology type.

7.2. Effects Decision Tree

Determine an Effects Scenario and refer to sections 8.3.



The energy resource is

Wind…………………………………………………………………… Go to A

Tidal…………………………………………………………………… Go to B

Waves…………………………………………………………………… Go to C

A. The wind turbine foundation is

Monopile…………………………………………………………………… Go to A1

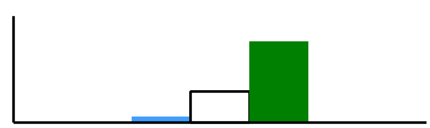
Gravity…………………………………………………………………… Go to A2

Tripod/Lattice…………………………………………………………………… Go to A3

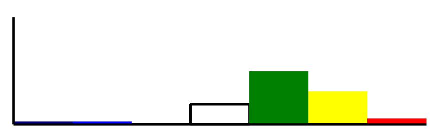
Floating mooring…………………………………………………………………… Go to A4

A1. The monopile wind turbine project scale is

Demonstration…………………………………………… Go to E1

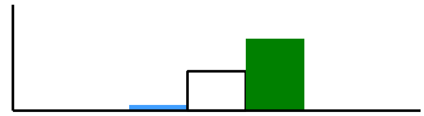


Commercial/Multiple commercial……………….. Go to E2

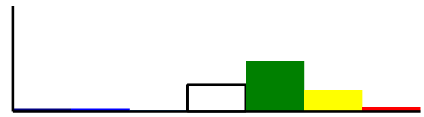


A2. The gravity wind turbine project scale is

Demonstration………………………………………………. Go to E1

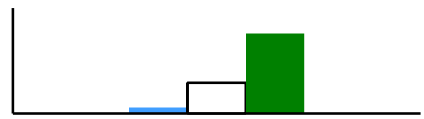


Commercial/Multiple commercial……………….. Go to E3

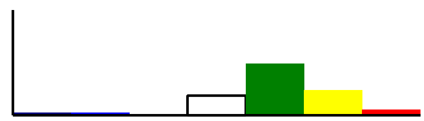


A3. The tripod/lattice wind turbine project scale is

Demonstration………………………………….. Go to E1

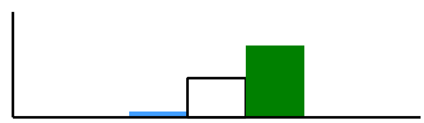


Commercial/Multiple commercial……………….. Go to E2

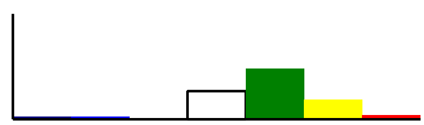


A4. The floating mooring wind project scale is

Demonstration………………………………………………. Go to E1



Commercial/Multiple commercial……………….. Go to E3



B. The tidal turbine type is

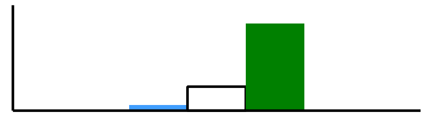
Open, bottom mounted…………………………………………………………………………………Go to B1

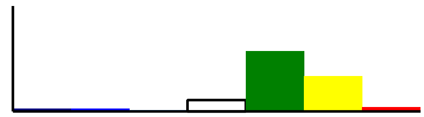
Open, floating mooring…………………………………………………………………………….. Go to B2

Shrouded, bottom mounted………………………………………………………………….. Go to B3

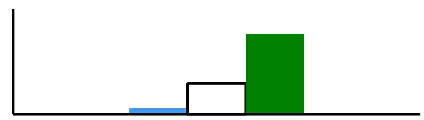
Shroued, floating mooring.. Go to B4

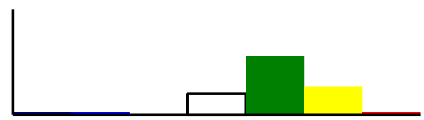
B1. The open rotor, bottom-mounted tidal turbine project scale is

Demonstration.. Go to E1 

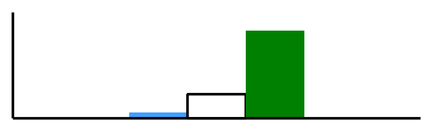
Commercial/Multiple commercial.................... Go to E4 

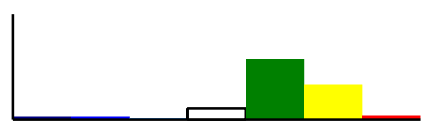
B2. The open rotor, floating mooring tidal turbine project scale is

Demonstration.. Go to E1 

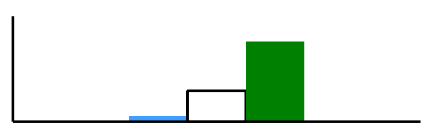
Commercial/Multiple commercial.................... Go to E5 

B3. The shrouded rotor, bottom-mounted tidal turbine project scale is

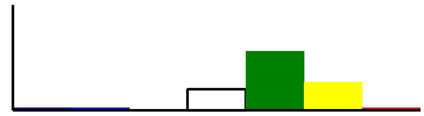
Demonstration.. Go to E1 

Commercial/Multiple commercial.................... Go to E4 

B4. The shrouded rotor, floating mooring tidal turbine project scale is

Demonstration.. Go to E1 

Commercial/Multiple commercial……………….. Go to E5



C. The wave device type is

Point absorber……………………………………………………………………………………………… Go to C1

Wave attenuator………………………………………………………………………………………… Go to C2

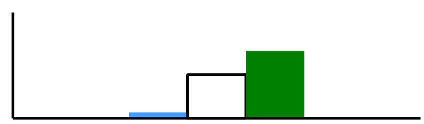
Oscillating water column…………………………………………………………………………… Go to C3

Oscillating wave surge converter……………………………………………………………… Go to C4

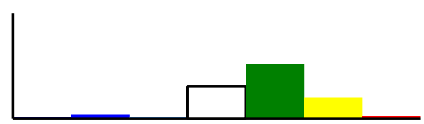
Overtopping…………………………………………………………………………… Go to C5

C1. The point absorber project scale is

Demonstration…………………………………………… Go to E1

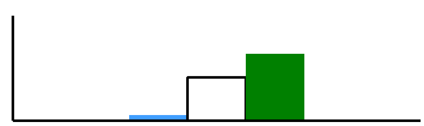


Commercial/Multiple commercial……………….. Go to E6

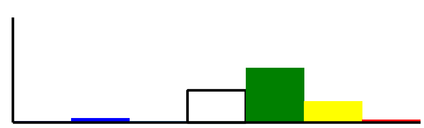


C2. The wave attenuator project scale is

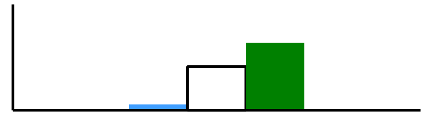
Demonstration…………………………………………… Go to E1

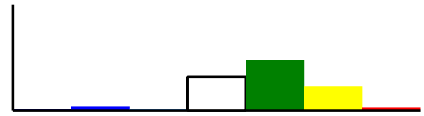


Commercial/Multiple commercial……………….. Go to E6

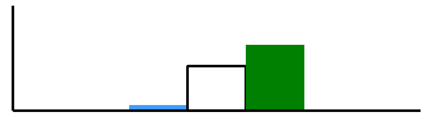


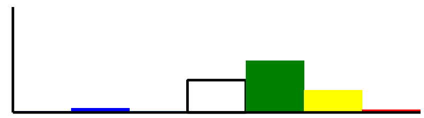
C3. The oscillating water column device project scale is

Demonstration…………………………………………… Go to E1 

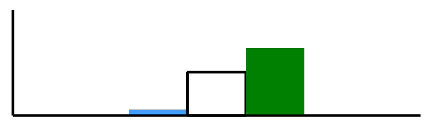
Commercial/Multiple commercial……………….. Go to E6 

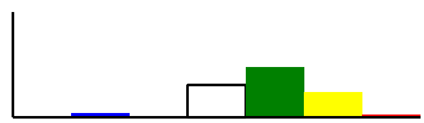
C4. The oscillating wave surge converter project scale is

Demonstration…………………………………………… Go to E1 

Commercial/Multiple commercial……………….. Go to E6 

C5. The overtopping device project scale is

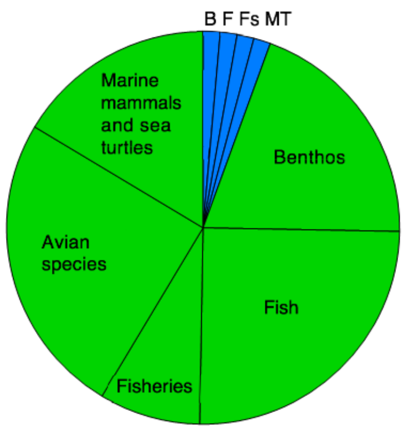
Demonstration…………………………………………… Go to E1 

Commercial/Multiple commercial……………….. Go to E6 

7.3. EFFECT EFFECTS SCENARIOS (E1 – E6)

Each Effect Scenario is described below in narrative form and by a pie chart. The pie charts represent the total number of effects for each Scenario, categorized by whether the effect is positive (blue), minor negative (green), moderate negative (yellow) and major negative (red); using the effect levels described in section 2.0. Each of the effect-level sections of the pie is further broken down by ecosystem component (the abbreviations used on the pie charts are: B = Benthic Habitat and Resources; F = Fish Species; Fs = Fishing Activity; A = Avian Species; MT = Marine Mammals and Sea Turtles). In this way, users can quickly determine the proportion and magnitude of effects on each ecosystem component for each development scenario. The pie charts should be used to decide which ecosystem components should receive priority monitoring attention based on the proportion of moderate and major negative effects that it may experience. Similarly, users might refer to the pie charts to determine a weighting scheme for a cumulative impact assessment. For example, in Effects Scenario E5, only Benthic Habitat and Resources and Fisheries are estimated to experience major effects, and could perhaps be given special attention during monitoring (or higher weights in a cumulative impact assessment) of E5 development types.

7.3.1. Effects Scenario E1—All Demonstration-scale Projects

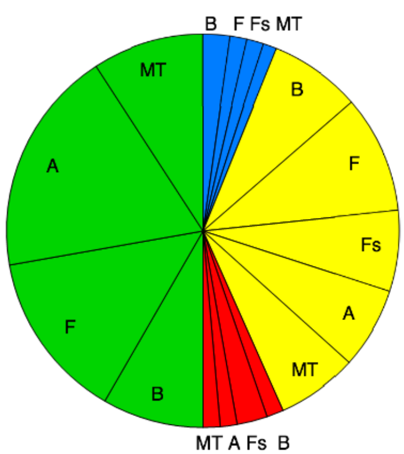


Demonstration-scale projects are listed as "Scale 1" in the Renewable Energy Effects Matrix. The current literature suggests that any ORE development, if completed at the demonstration scale, will not have any moderate or major effects on the ecosystem components examined here. Therefore, we list the **potential minor effects** and their certainty in the Effects Decision Tree. Of the suite of minor effects, Benthic Habitat and Resources, Avian Species, and Fish Species share equally high proportions. Across ecosystem components, effects with the highest certainty tend to be physical and chemical disturbances, such as disturbance from device installation, attraction to devices, or chemical spills. Effects with low certainty include noise (except for Marine Mammals and Sea Turtles where the certainty for this effect is high), changes to energy regimes, and changes in organism energetic expense. EMF is the only effect that has low certainty consistently across all ecosystem components. Only those potential effects with high certainty are listed in the decision tree; where certainty is low, it may be impossible to detect any effect.

Component (not ranked)	**Minor Effect**	**Certainty**
Benthic Habitat and Resources	Disturbance from installation/removal of device (including turbidity)	HIGH
	Disturbance from installation or removal of power cable (including trenching)	HIGH
	Scour around structures	HIGH
	Smothering by excavated sediments	HIGH
	Reef effects	HIGH
	Diffusion/flaking of marine coating	HIGH
	Chemicals discharged during installation or removal	HIGH
	Resuspension of pollutants in sediments	HIGH

Fish Species and Fishing Activity	Disturbance from installation or removal of device	HIGH
	Disturbance from installation or removal or power cable	HIGH
	Reef effects	HIGH
	Loss of access to grounds during construction	HIGH
	Loss of access to grounds during operation	HIGH
Avian Species	Displacement or attraction to structure above surface of the water (wind turbines)	HIGH
	Displacement or attraction to structure below the surface of the water	HIGH
	Disturbance from installation of device or transmission cable	HIGH
	Collision with rotating turbine blades	HIGH
Marine Mammals and Sea Turtles	Strike by installation or support vessel	HIGH
	Leakage or discharge of chemicals; spills or accidents	HIGH
	Resuspension of pollutants in sediments	HIGH
	Operational noise – wind turbines	HIGH
	Noise from pile driving	HIGH
	Noise from directional drilling for power cable	HIGH
	Noise from vessel traffic	HIGH
	Noise from pile cutting during device removal	HIGH

7.3.2. Effects Scenario E2—Wind Turbine Developments Involving Pile Driving



This scenario includes monopile wind turbine developments and jacketed or tripod-mounted turbines at development Scales 2 and 3. If the proposed development will not utilize pile driving to install the jacketed or tripod structures, then Effects Scenario E3 is more appropriate. The effects that make this scenario unique are the presence of turbines above the water surface, the piles drilled into the seabed, and the noise associated with this activity. Therefore, the expected major effects include noise, scour and/or deposition around the structures, displacement or attraction to structures, and loss of access to mobile-gear fishing grounds.

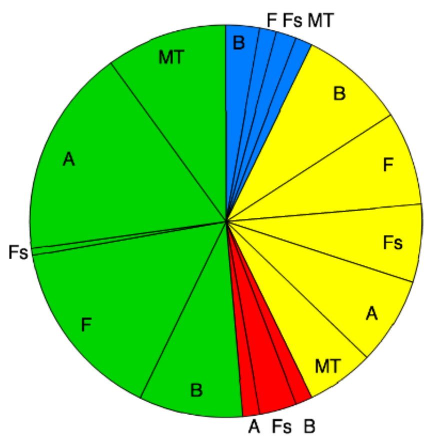
Notable moderate effects include resuspension of pollutants, loss of access to recreational and fixed-gear fishing grounds, decreased catchability (Fishing Activity), damaged/lost fishing gear, and collisions and strikes for Avian Species, Marine Mammals, and Sea Turtles. Reef effects are likely for Benthic Habitat and Resources and Fish Species at these developments. At this stage of knowledge and study, the profiles of effects between Scale 2 and Scale 3 differ primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3).

Priority	Major Effects	Certainty
1. Fish Species and Fishing Activity	Loss of access to grounds during construction and operation (mobile gear)	HIGH
2. Avian Species	Displacement or attraction to structure above water surface	HIGH
3. Benthic Habitat and Resources	Scour and/or deposition	HIGH
4. Marine Mammals and Sea Turtles	Noise from pile driving	MEDIUM

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	Resuspension of pollutants in sediments	HIGH
	Chemical spills, discharge	MEDIUM
	Disturbance from installation of cable	MEDIUM
	Changes to current/wave regime	MEDIUM
Fish Species and Fishing Activity	Chemical spills	MEDIUM
	Operational noise	MEDIUM
	Noise from pre-construction seismic surveys	MEDIUM
	Noise from pile driving	MEDIUM
	Noise from pile cutting during device removal	MEDIUM
	EMF	LOW
	Habitat/community composition alteration	MEDIUM
	Decreased catchability during construction and operation	MEDIUM
	Loss of access to grounds during construction and operation (fixed gear and recreational)	HIGH
	Changes in species distribution	LOW
	Damaged/lost gear	HIGH

Avian Species	Displacement or attraction to structure below water surface	MEDIUM
	Collision with rotating turbine blades	HIGH
	Pressure gradients around rotor	MEDIUM
	Leakage of lubricants/fluids; release of maintenance chemicals	MEDIUM
	Large chemical spills	HIGH
Marine Mammals and Sea Turtles	Entanglement with mooring lines or cables	MEDIUM
	Strikes with installation or support vessels	HIGH
	Operational noise	MEDIUM
	Noise from pile cutting during device removal	HIGH

7.3.3. Effects Scenario E3—Wind Turbine Developments Involving No Pile Driving

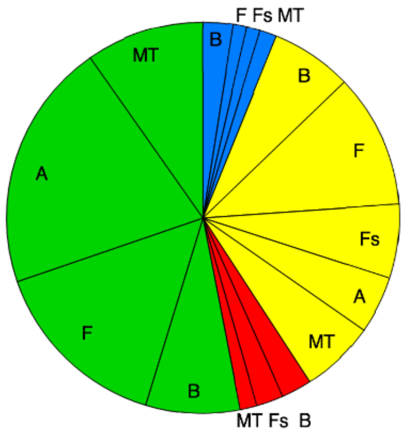


Floating-mooring or gravity-base foundations present a different suite of effects for wind-turbine developments at Scales 2 and 3. A major effect in Scenario E2—noise during construction—is now absent. The suite of the remaining negative effects for each ecosystem component is very similar to E2, with the exception of Benthic Habitat and Resources. Gravity-base foundations incur a moderate negative effect through physical disturbance to the sediment, where in E2 this effect is classified as minor. Reef effects are likely for Benthic Habitat and Resources and Fish Species at these developments. At this stage of knowledge and study, the profile of effects between Scale 2 and Scale 3 differs primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3).

Priority	Major Effects	Certainty
1. Fish Species and Fishing Activity	Loss of access to grounds during construction and operation (mobile gear)	HIGH
2. Avian Species	Displacement or attraction to structure above water surface	HIGH
3. Benthic Habitat and Resources	Scour and/or deposition	HIGH

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	Resuspension of pollutants in sediments	HIGH
	Disturbance from installation/removal of device (turbidity)	MEDIUM
	Chemical spills, discharge	MEDIUM
	Disturbance from installation of cable	MEDIUM
	Changes to current/wave regime	MEDIUM
Fish Species and Fishing Activity	Chemical spills	MEDIUM
	Operational noise	MEDIUM
	Noise from pre-construction seismic surveys	MEDIUM
	Noise from pile cutting during device removal	MEDIUM
	EMF	LOW
	Habitat/community composition alteration	MEDIUM
	Decreased catchability during construction and operation	MEDIUM
	Loss of access to grounds during construction and operation (fixed gear and recreational)	HIGH
	Changes in species distribution	LOW
	Damaged/lost gear	HIGH
Avian Species	Displacement or attraction to structure below water surface	MEDIUM
	Collision with rotating turbine blades	HIGH
	Pressure gradients around rotor	MEDIUM
	Leakage of lubricants/fluids; release of maintenance chemicals	MEDIUM
	Large chemical spills	HIGH
Marine Mammals and Sea Turtles	Entanglement with mooring lines or cables	MEDIUM
	Strikes with installation or support vessels	HIGH
	Operational noise	MEDIUM

7.3.4. Effects Scenario E4—Bottom-mounted Tidal Turbine Projects

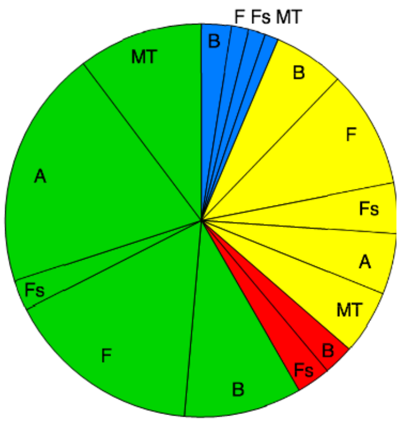


For tidal turbine developments, the profile of effects tended to differ more based on the foundation type than on whether the rotor is shrouded or open. Potential major effects at these developments include changes to hydrodynamics, scour and/or deposition around devices/moorings, loss of access to mobile-gear fishing grounds, and noise from pile driving. If the proposed development will not utilize pile driving to install the tidal turbines, then Effects Scenario E5 is more appropriate. Notable moderate effects include physical disturbance to the sediment; collisions/strikes to rotor blades for Fish Species, Avian Species, Marine Mammals, and Sea Turtles; the effects of rotor wake/pressure gradients to Fish and Avian Species; collisions/strikes with construction or support vehicles for Marine Mammals and Sea Turtles; and decreased catchability and damaged/lost gear for Fishing Activity. At this stage of knowledge and study, the profile of effects between Scale 2 and Scale 3 differs primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3).

Priority	Major Effects	Certainty
1. Benthic Habitat and Resources	Changes in hydrodynamics Scour and/or deposition	MEDIUM HIGH
2. Fish Species and Fishing Activity*	Loss of access to grounds during construction and operation (mobile gear)	HIGH
3. Marine Mammals and Sea Turtles*	Noise from pile driving	MEDIUM

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	Resuspension of pollutants in sediments	LOW
	Disturbance from installation/removal of device (turbidity)	HIGH
	Chemical spills, discharge	MEDIUM
	Disturbance from installation of cable	MEDIUM
	Changes to current/wave regime	MEDIUM
Fish Species and Fishing Activity	Collision/blade strike	MEDIUM
	Pressure gradients around rotor	MEDIUM
	Chemical spills	MEDIUM
	Operational noise	MEDIUM
	Noise from pre-construction seismic surveys	MEDIUM
	Noise from pile driving	MEDIUM
	Noise from pile cutting during device removal	MEDIUM
	EMF	LOW
	Habitat/community composition alteration	MEDIUM
	Decreased catchability during construction and operation	MEDIUM
	Loss of access to grounds during construction and operation (fixed gear and recreational)	HIGH
	Changes in species distribution	LOW
	Damaged/lost gear	HIGH
Avian Species	Collision with rotating turbine blades	MEDIUM
	Pressure gradients around rotor	MEDIUM
	Leakage of lubricants/fluids; release of maintenance chemicals	MEDIUM
	Large chemical spills	HIGH
Marine Mammals and Sea Turtles	Entanglement with mooring lines or cables	MEDIUM
	Strikes with installation or support vessels	HIGH
	Operational noise	MEDIUM
	Noise from pile cutting during device removal	HIGH

7.3.5. Effects Scenario E5—Floating-mooring Tidal Turbine Projects



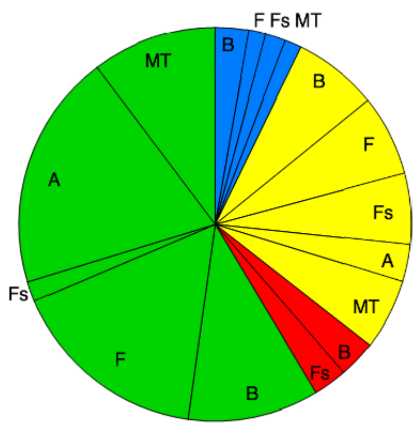
Floating-mooring foundations present a different suite of effects for tidal turbine developments at Scales 2 and 3. A major effect in Scenario E4—noise during construction—is now absent. The suite of remaining negative effects for each ecosystem component is very similar to E4, with exceptions for Benthic Habitat and Resources and Fishing Activity. The effects from sediment disturbance in this scenario are downgraded to minor, as are the effects surrounding decreased catchability. At this stage of knowledge and study, the profile of effects between Scale 2 and Scale 3 differs primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3).

Priority	Major Effects	Certainty
1. Benthic Habitat and Resources	Changes in hydrodynamics	MEDIUM
	Scour and/or deposition	HIGH
2. Fish Species and Fishing Activity*	Loss of access to grounds during construction and operation (mobile gear)	HIGH

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	Resuspension of pollutants in sediments	LOW
	Chemical spills, discharge	MEDIUM
	Disturbance from installation of cable	MEDIUM
	Changes to current/wave regime	MEDIUM
Fish Species and Fishing Activity	Collision/blade strike	MEDIUM
	Pressure gradients around rotor	MEDIUM
	Chemical spills	MEDIUM
	Operational noise	MEDIUM
	Noise from pre-construction seismic surveys	MEDIUM
	EMF	LOW

	Habitat/community composition alteration	MEDIUM
	Loss of access to grounds during construction and operation (fixed gear and recreational)	HIGH
	Changes in species distribution	LOW
	Damaged/lost gear	HIGH
Avian Species	Collision with rotating turbine blades	MEDIUM
	Pressure gradients around rotor	MEDIUM
	Leakage of lubricants/fluids; release of maintenance chemicals	MEDIUM
	Large chemical spills	HIGH
Marine Mammals and Sea Turtles	Entanglement with mooring lines or cables	MEDIUM
	Strikes with installation or support vessels	HIGH
	Operational noise	MEDIUM

7.3.6 Effects Scenario E6—Wave Energy Projects



In general, all wave energy developments are less well studied than tidal or wind developments. Therefore, we caution against the interpretation that the pie chart suggests that wave energy developments have a lower proportion of potential major and moderate effects than any other development type. Major effects at Scale 2 and Scale 3 wave energy projects are changes in hydrodynamics, scour and/or deposition around devices, and loss of access to mobile gear fishing grounds. Notable moderate effects include loss of access to fixed gear and recreational fishing grounds, damaged/lost fishing gear, chemical spills, and collisions/strikes with construction or support vehicles for Marine Mammals and Sea Turtles. Specifically, oscillating wave-surge converters have higher potential effects over the other types (moderate versus minor) for operational noise on Fish Species, Marine Mammals, and Sea Turtles, and for sediment disturbance on Benthic Habitat and Resources. Overtopping devices pose an increased potential negative effect over other types (moderate versus minor) on Avian Species for displacement or attraction to the device because of the above-water structure. At this stage of knowledge and study, the profile of effects between Scale 2 and Scale 3 differs primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3.

Priority	Major Effects	Certainty
1. Benthic Habitat and Resources	Changes in hydrodynamics	MEDIUM
	Scour and/or deposition	HIGH
2. Fish Species and Fishing Activity*	Loss of access to grounds during construction and operation (mobile gear)	HIGH

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	Resuspension of pollutants in sediments	LOW
	Chemical spills, discharge	MEDIUM
	Disturbance from installation of cable	MEDIUM
	Changes to current/wave regime	MEDIUM
Fish Species and Fishing Activity	Chemical spills	MEDIUM
	Operational noise	MEDIUM
	Noise from pre-construction seismic surveys	MEDIUM
	EMF	LOW
	Habitat/community composition alteration	MEDIUM
	Decreased catchability during construction/operation	MEDIUM
	Loss of access to grounds during construction and operation (fixed gear and recreational)	HIGH
	Changes in species distribution	MEDIUM
	Damaged/lost gear	HIGH
Avian Species	Displacement/attraction to structure above water surface	MEDIUM
	Leakage of lubricants/fluids; release of maintenance chemicals	MEDIUM
	Large chemical spills	HIGH
Marine Mammals and Sea Turtles	Entanglement with mooring lines or cables	MEDIUM
	Strikes with installation or support vessels	HIGH
	Operational noise	MEDIUM

* Higher priority may be given to this component due to national/regional/local regulatory objectives and obligation

8. COMPONENT DECISION TREES AND MONITORING PROTOCOLS

We present the Component Decision Trees and summaries of the Monitoring Protocols for each of the topic areas (ecosystem components)— benthic habitat and resources, fishery resources and fishing activities, avian species, marine mammals, and sea turtles. The output of each Component Decision Tree is a recommended selection of Monitoring Protocols for a given ORE project. Each of the protocols described here is intended to represent the best monitoring practices and methodologies at the time of writing this document. An extensive literature review was conducted (see Task 1.3 Report) to identify methods used for monitoring for existing ORE projects and other offshore construction in the United States and around the world. Subject-area experts were consulted (see Appendix C) to develop a consensus on and validate the protocols selected for inclusion in this report.

These protocols were developed to answer questions about potential effects as described in our Task 1.2 Report, and summarized in Section 8 above. As described in Section 4, we propose a series of indicators for these effects, particularly those that are not easily directly observed. In other cases, we did not create a monitoring protocol for a particular effect, either because the level of certainty of the effect is very low (making it difficult to develop a study that can isolate this particular effect, especially if the effect is not well understood), or because the likelihood of the effect is very small. This is the case for many of the potential effects related to leaking or spills of chemicals; while the level of impact from an event could be high, the probability of the event is low.

8.1. Time Scales and Cost

The time scales of monitoring protocols should be long enough to observe short-term or immediate impacts caused by an ORE development, include enough data to limit some of the effects of natural variability on the analysis, and last long enough to observe whether conditions return to a pre-construction state. Developer-led monitoring will probably not be conducted on time scales of a length sufficient to observe very long-term effects from ORE projects (i.e., decades). Supplementary monitoring should be conducted for a decade or more in order to understand long-term effects. For example, five years of monitoring may be enough time to observe effects on some individuals and/or communities, but may not be sufficient to identify stock- or population-level effects, particularly on slow-growing or long-lived species such as elasmobranchs. Additionally, some have speculated that if ORE devices result in reef effects, this could create secondary effects such as larval spillover if spawning is occurring around the devices. These sorts of secondary effects may not be observable during the time scales of developer-led monitoring. Thus we recommend that, where feasible, monitoring and supplementary studies take place well beyond the minimum time frames required by federal permitting agencies.

We recognize that the cost of monitoring is often a substantial factor in selecting the methodologies, scale, and duration. We have indicated the relative cost of each protocol to help regulators and developers select which to use in cases where more than one option is available. Because it is difficult to estimate exact cost without knowing project-specific details, we have created a cost scale of Low (less than $100,000), Medium ($100,000 - $500,000), and High (greater than $500,000) that is used in the protocols.

8.2. COMPONENT DECISION TREE FOR BENTHIC HABITAT AND RESOURCES

Determine which impacts to Benthic Habitat and Resources need to be monitored:

The energy resource is

Wind……………………………………………………………………………………………Go to A

Waves…………………………………………………………………………………………Go to B

Tidal……………………………………………………………………………………………Go to C

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice…………………………………………………Go to A1

Gravity………………………………………………………………………………………Go to A2

Floating mooring……………………………………………………………………Go to A3

A1. The stage of the monopile, tripod, or lattice wind turbine project is

Construction…………………………………………………………W1, W2

Operation……………………………………………………………W1, W2, W3

Decommissioning……………………………………………………W1, W2

A2. The stage of the gravity wind turbine project is

Construction…………………………………………………………W1, W2, W3

Operation……………………………………………………………W1, W2, W3

Decommissioning……………………………………………………W1, W2, W3

A3. The stage of the floating mooring wind project is

Construction….. W1, W2

Operation…….. W1, W2

Decommissioning………………..W1, W2

B. The tidal turbine type is

Open OR shrouded bottom-mounted.. Go to B1

Open OR shrouded floating mooring….. Go to B2

B1. The stage of the bottom-mounted tidal turbine project is

Construction….. W1, W2

Operation…... W1, W2, W3, W4

Decommissioning……………….. W1, W2

B2. The stage of the floating mooring tidal turbine project is

Construction…... W1, W2

Operation….. W1, W2, W4

Decommissioning……………….. W1, W2

C. The wave device type is

Point absorber OR Wave attenuator OR Oscillating Water column……………. Go to C1

Oscillating wave surge converter…..Go to C2

Overtopping……... Go to C3

C1. The stage of the point absorber OR wave attenuator OR oscillating water column project is

Construction.. W1, W2

Operation... W2, W4

Decommissioning..W1, W2

C2. The oscillating wave surge converter project scale is

Construction... W1, W2

Operation...W1, W2, W3, W4

Decommissioning W1, W2

C3. The overtopping device project scale is

Construction...W1, W2

Operation..W1, W2, W4

Decommissioning... W1, W2

Recommended protocols:

W1. Seabed scour and/or deposition

W2. Changes in benthic community composition

W3. Increase in hard bottom habitat

W4. Changes in hydrodynamics

8.3. MONITORING PROTOCOLS FOR BENTHIC HABITAT AND RESOURCES

Benthic Habitat and Resources Monitoring Protocol W1: Sediment Scour and/or Deposition

MONITORING OBJECTIVE: Sediment scour and/or deposition

Indicator(s) of the impact	Scour: increase in median grain size; decrease in organic content; decrease in seabed volume Deposition: decrease in median grain size; increase in organic content; increase in seabed volume	
Methodology or Technique to Collect Data	Particle size analysis; Multibeam/interferometric bathymetry	
Description of Methodology or Technique(s) for collecting data	Seasonal surveys, 5 years Grain size: *5-sample transect at 3 devices out to 200m Bathymetry: overlapping transects for 100% coverage (at least 0.5 m pixels) 1 km radius at 3 devices	Annual surveys, 3 years Grain size: *3-sample transect at 3 devices out to 200m Bathymetry: overlapping transects for 100% coverage (at least 0.5 m pixels) 500m radius 3 devices
Methodology for Analyzing data	ANOVA on median grain size Volume change estimate using mosaicked bathymetry models	
Frequency and Duration	1 preconstruction survey Seasonal operation surveys 1 postconstruction survey	1 preconstruction survey Annual operation surveys 1 postconstruction survey
Spatial Scale	200m – 1km radius around 3 devices	500m radius around 3 devices
Other Considerations **(E.g. Advantages or Disadvantages)**	Accounts for Seasonal and interannual variability	Accounts for interannual variability
Relationship to Other Protocols	Can be combined with benthic community composition monitoring protocol (Protocol Z2)	
Cost (High, Medium, Low)	Medium	Low
Data Format	Data table time series	
Data Output	Time series values for median grain size and standard deviations Time series on volume at each turbine and standard deviation	
Examples where this methodology has been used	Degraer et al., 2011; Saunders et al., 2011	

Benthic Habitat and Resources Monitoring Protocol W2: Changes in benthic community composition

MONITORING OBJECTIVE: Changes in benthic community composition

Indicator(s) of the impact	Change in abundance, diversity, % cover, multivariate community composition	
Methodology or Technique to Collect Data	Grab samples (Smith McIntyre or similar) ~0.1m^2/sample (soft bottom) Underwater video transects (soft and hard bottom)	
Description of Methodology or Technique(s) for collecting data	Seasonal surveys, 5 years *5-sample transect at 5 devices out to 200m **200m UWvideo at each device AND at reference station <1km	Annual surveys, 3 years *3-sample transect at 3 devices out to 200m **200m UWvideo at 3 device AND at reference station <1km
Methodology for Analyzing data	ANOVA on abundance, diversity, % cover ANOSIM on community composition: over time and between ORED and reference	
Frequency and Duration	1 preconstruction survey Seasonal operation surveys 1 postconstruction survey	1 preconstruction survey Annual operation surveys 1 postconstruction survey
Spatial Scale	200 m radius around 5 devices	200m radius around 3 devices
Other Considerations **(E.g. Advantages or Disadvantages)**	Accounts for seasonal and interannual variability	Accounts for interannual variability
Relationship to Other Protocols	Can be combined with scour/deposition monitoring protocol (Protocol W1) Can be combined with reef effects monitoring protocol (Protocol W3)	
Cost (High, Medium, Low)	Medium	Low
Data Format	Data table time series	
Data Output	Time series values for abundance, diversity, % cover and standard deviations Time series summary metric on benthic community composition (Indicator species, SIMPER, etc.)	
Examples where this methodology has been used	Degraer et al., 2011; Saunders et al., 2011	

Benthic Habitat and Resources Monitoring Protocol W3: Reef Effects

MONITORING OBJECTIVE: Increase in hard bottom habitat (reef effect) and non-native species

Indicator(s) of the impact	Increase in % cover, biomass of epifaunal organisms; increase in presence of non-native species	
Methodology or Technique to Collect Data	Diver imagery and scrape samples	
Description of Methodology or Technique(s) for collecting data	Seasonal surveys, 5 years Diver picture/video, then scrape and collect 0.25x0.25 m quadrat 3 quadrats per device (high, med low water) 3 devices	Annual surveys, 3 years 3 ROV video transect per device 3 devices
Methodology for Analyzing data	% cover estimate from imagery, dry weight biomass ANOVA	ANOVA on % cover, # species
Frequency and Duration	Seasonal during operation only	Annual during operation only
Spatial Scale	Small	Large
Other Considerations **(E.g. Advantages or Disadvantages)**	Accounts for seasonal and interannual variability	Accounts for interannual variability
Relationship to Other Protocols	Can be combined with Fisheries Monitoring Protocol X3	
Cost (High, Medium, Low)	Medium	Low
Data Format	Data table time series	
Data Output	Time series values for % cover, biomass Presence absence of non-native species	
Examples where this methodology has been used	Degraer et al., 2011	

Benthic Habitat and Resources Monitoring Protocol W4: Hydrodynamics

MONITORING OBJECTIVE: Changes in hydrodynamics

Indicator(s) of the impact	Change in residual flow rates; change in water column turbidity	
Methodology or Technique to Collect Data	Bottom-mounted acoustic Doppler current profilers (ADCPs) Turbidity sensors	
Description of Methodology or Technique(s) for collecting data	Seasonal surveys, 5 years 3 ADCP/turbidity sensor package in ORED 1 ADCP/turbidity at reference site	Annual surveys, 3 years 1 ADCP/turbidity sensor package in ORED 1 ADCP/turbidity at reference site
Methodology for Analyzing data	ANOVA time-average flow velocity Time-average turbidity	
Frequency and Duration	Preconstruction baseline survey Seasonal averages during operation	Preconstruction baseline survey Annual averages during operation
Spatial Scale	Transect across entire development	Point location within development
Other Considerations **(E.g. Advantages or Disadvantages)**	Depending on length of deployment, captures from tidal to interannual variability	
Relationship to Other Protocols	N/A	
Cost (High, Medium, Low)	Medium	Low
Data Format	Data table time series	
Data Output	Time series for time-averaged flow rates and turbidity values (tidal frequency, daily, monthly, seasonally, annually)	
Examples where this methodology has been used	Van den Eynde et al., 2011	

8.4. Component Decision Tree for Fisheries Resources and Fishing Activity

Determine which effects to Fisheries Resources and Fishing Activity need to be monitored:

The energy resource is

Wind………………………………………………………………………………………………….Go to A

Tidal………………………………………………………………………………………………….Go to B

Waves………………………………………………………………………………………………. Go to C

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice OR Gravity…………………………………………Go to A1

Floating mooring………………………………………………………………………… Go to A3

A1. The stage of the monopile, tripod, lattice, or gravity wind turbine project is

Construction……………………………………………………………………………X1, X2, X5

Operation………………………………………………………………………………X1, X2, X3, X5

Decommissioning……………………………………………………………………X1, X2

A2. The stage of the floating mooring wind project is

Construction…………………………………………………………………………………X1, X2, X5

Operation……………………………………………………………………………………X3, X4, X5

Decommissioning…………………………………………………………………………X1, X2

B. The tidal turbine type is

Open OR shrouded bottom-mounted.. Go to B1

Open OR shrouded floating mooring…………………………………………………… Go to B2

B1. The stage of the bottom-mounted tidal turbine project is

Construction…………………………………………………………………………X1, X2, X5

Operation……………………………………………………………………………X1, X2, X3, X4, X5

Decommissioning………………………………………………………………X1, X2

B2. The stage of the floating mooring tidal turbine project is

Construction………………………………………………………………………X1, X2, X5

Operation…………………………………………………………………………X1, X2 X3, X4, X5

Decommissioning……………………………………………………………X1, X2

C. The wave device type is

Point absorber OR Wave attenuator OR Oscillating Water column OR Overtopping…………………………………………………………………………………………… Go to C1

Oscillating wave surge converter…………………………………………………………… Go to C2

C1. The stage of the point absorber OR wave attenuator OR oscillating water column OR overtopping project is

Construction.……………………………………………………………………………………… X1, X2, X5

Operation…………………………………………………………………………………………… X1, X2, X5

Decommissioning………………………………………………………………………………X1, X2

C2. The oscillating wave surge converter project scale is

Construction.. X1, X2, X5

Operation.. X1, X2, X3, X5

Decommissioning X1, X2

Recommended protocols:

X1. Meso-scale changes to abundance and distribution (disturbance)

X1a. The species of concern are finfish

X1b. The species of concern are crustaceans or rock fish

X2.Habitat alteration/community composition: Micro-scale changes to abundance and distribution - finfish

X3. Reef effects

X4. Blade strikes

X5. Spatial use of fishing activity

8.5. MONITORING PROTOCOLS FOR FISHERIES RESOURCES AND FISHING ACTIVITY

Fisheries Protocol X1a- Trawl Surveys

MONITORING OBJECTIVE: Monitor for changes in meso-scale distribution and abundance of fish species in the vicinity of an offshore renewable energy installation

(Can also be applied for pre-siting baseline studies)

Indicator(s) of the impact	Shift in fish distribution or abundance overall or on a seasonal basis; shift in species composition; increase or decrease in catch per unit effort of commercially or recreationally targeted species
Methodology or Technique to Collect Data	Otter Trawl Survey
Description of Methodology or Technique(s) for collecting data	• Using BACI design with multiple control locations outside of the project area • Control locations selected to have similar bottom types and benthic habitat as project area trawl locations • Trawl locations from random station grid • Surveys conducted a minimum of four times/year • Baseline trawl locations and paths will be selected to be able to follow the same route after construction • All fish species sampled, with particular attention paid to commercially, recreationally, and ecologically important species • Sampling of weight and length of species • One inch knotless cod end liner • Trawl speed of 2.9 – 3.3 knots • Trawl lasting duration of 20 minutes (depending on the size of the net)
Methodology for Analyzing data	ANOVA on numbers of individuals, size and weight distribution; multivariate analysis of catch/community composition, multidimensional scaling, cluster analysis
Frequency and Duration	• 2 years of baseline data in pre-construction period (surveys at least 4 times/year both years) • 4 surveys/year during post-construction for minimum of 5 years • Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	• Random stratified surveys selected from the following stratification: 10 sites within .5 km of renewable energy site; 10 sites between .5-2.5 km of renewable energy site; 10 control sites (at greater than 2.5 km from site) • Control sites should be selected from areas with similar bathymetry and bottom type to renewable energy site • A minimum of 30 trawls per survey period
Other Considerations (E.g. Advantages or Disadvantages)	• Not all survey types and gear types will be appropriate to each location. The gear and survey types should be selected based on the issues of greatest concern.

	• Trawl survey will sample mostly demersal species rather than pelagic species. Survey limited to those species most prone to be caught in the net, and will under-sample some species, e.g. lobsters and crabs. • The commercial fishing industry should be consulted on the type of gear used. • The commercial fishing industry should be involved in data collection and survey design when feasible, including the selection of trawl stations. • Accounts for seasonal and annual variability.
Relationship to Other Protocols	Can be combined with Fisheries Protocol X1b or X2
Cost (High, Medium, Low)	Medium (Annually, depending on the number of surveys)
Data Format	• Total individuals/area • Total biomass/area • # Individuals per species and area • Biomass per species and area • Diversity • Length frequency distribution of dominant species • Time series
Data Output	Catch per unit effort (CPUE) for total catch and on a species level; community dynamics
Examples where this methodology has been used	Bundesamt für Seeschifffahrt und Hydrographie, 2007; Bonzek et al. 2008; CEFAS 2004.

Fisheries Protocol X1b - Ventless Trap Surveys

MONITORING OBJECTIVE: Monitor for changes in distribution and abundance of lobster/crab species or some fish species in the vicinity of an offshore renewable energy installation

Indicator(s) of the impact	Shift in distribution of lobster, crab, or rock fish, or abundance overall or on a seasonal basis; shift in species composition; increase or decrease in catch per unit effort of species by commercial fishing gear
Methodology or Technique to Collect Data	Fixed Gear Survey with Ventless Traps
Description of Methodology or Technique(s) for collecting data	• Using BACI design with multiple control locations • Surveys conducted in spring and fall • Control locations selected to have similar bottom types and benthic habitat as project area trawl locations • Sampling of weight and length of species
Methodology for Analyzing data	ANOVA on numbers of individuals, size and weight distribution; multivariate analysis of catch/community composition
Frequency and Duration	• 2 years of baseline data in pre-construction period (seasonal surveys 4 x/year both years) • Seasonal (4/year) during post-construction for minimum of 5 years • Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	Traps set within the renewable energy installation, and at random stratified sites at varying distances from the renewable energy site (e.g. 1 km, 10 km, 25 km)
Other Considerations (E.g. Advantages or Disadvantages)	• Not all survey types and gear types will be appropriate to each location. The gear and survey types should be selected based on the issues of greatest concern. • The gear and techniques used by the commercial fishing industry should be mirrored in the survey design when sampling commercially-important fish species. • The commercial fishing industry should be involved in data collection and survey design when feasible. • While ventless trap surveys are often used for crustaceans, they may be useful for species such as black sea bass, rock fish, or other species that are attracted to structures and can be caught by traps or pots. • Accounts for seasonal and annual variability.
Relationship to Other Protocols	Can be combined with Fisheries Protocol X1a or X2
Cost (High, Medium, Low)	Low
Data Format	• Total individuals/area • Total biomass/area • # Individuals per species and area

	• Biomass per species and area • Length frequency distribution of dominant species
Data Output	Catch per Unit Effort (CPUE) at species level
Examples where this methodology has been used	Maine Department of Marine Fisheries, 2006; Courchene and Stokesbury, 2011.

Fisheries Protocol X2- Monitoring for project-scale changes

MONITORING OBJECTIVE: Monitor for micro-scale changes in abundance or species composition of fish around renewable energy structures or along cable routes, including non-native species, resulting from disturbance (from noise, presence of devices), or attraction to devices (aggregation or reef effects); Monitor for changes in catch per unit effort of commercially and recreationally targeted fish in the vicinity of the ORED

Indicator(s) of the impact	Increase or decrease in fish abundance; increase or decrease in target species; shift in species composition; increase in presence of non-native species; increase or decrease in catch per unit effort of commercially or recreationally targeted species
Methodology or Technique to Collect Data	Gillnet surveys and/or trammel net surveys and/or beam trawl surveys
Description of Methodology or Technique(s) for collecting data	• Gillnet or trammel net surveys: • Installation-based surveys a minimum of 6 days/year • Three deployments each spring and fall for 1-2 days each • Installation at a minimum of three locations within footprint of renewable energy facility, and three reference locations in similar habitat, no less than 1km from footprint sites • Beam trawl surveys: • Seasonal tows (spring, summer, fall, winter) • minimum of 3 locations within the footprint of the installation (between devices) - if possible • 9 ft. beam trawl with 1 in. knotless liner recommended • Tows at a minimum of three locations within footprint of renewable energy facility, and three reference locations in similar habitat, no less than 1km from footprint sites • Survey area can be expanded to include cable route, particularly when electromagneto-sensitive species (e.g. elasmobranchs) are of concern
Methodology for Analyzing data	ANOVA on # species, # of fish, multivariate analysis of fish community characteristics (Primer-E), multidimensional scaling, cluster analysis
Frequency and Duration	• Baseline survey pre-construction (4 surveys, one each in spring, summer, fall, and winter) • Seasonal (4 times/year) during operation for 3 years
Spatial Scale	• <u>Gillnets/Trammel nets</u>: Minimum of three installations within renewable energy footprint, and an equal number of reference stations in similar habitat • <u>Beam trawl:</u> Minimum of three locations within renewable energy footprint, and an equal number of reference stations in similar habitat
Other Considerations (E.g. Advantages or Disadvantages)	• Gear type(s) used for the survey should depend on the fish species under consideration (commercially/recreationally important species, species of conservation importance), and the gear type that will be most effective in assessing changes to the abundance and distribution of these species on a fine scale. • Gillnet surveys will undersample demersal species but can sample pelagic species, which are difficult to sample by other means.

	• Gillnets are fairly size selective and will not provide a good estimate of overall biomass of the area. • Combining gillnet and beam trawl surveys can account for a larger spectrum of fish species. • Trammel nets can capture more fish than gillnets and will provide a greater picture of size distribution. • However, trammel nets can be highly destructive and need to be checked or removed frequently. • Passive nets can be deployed much closer to the devices than active trawling. • Beam trawls can supplement otter trawls by trawling within an offshore renewable energy installation or between devices to sample within the footprint of a project, where otter trawling may not be feasible. • Beam trawls can also sample harder bottom habitats and are more effective at assessing benthic invertebrates (e.g. scallops, lobsters, clams, crabs). • Can account for seasonal and interannual variability.
Relationship to Other Protocols	Can be combined with Fisheries Protocol X1a or X1b
Cost (High, Medium, Low)	Low
Data Format	• Gillnet/trammel net: Catch per unit effort (CPUE) # Individuals per species and area Diversity Length frequency distribution of dominant and/or vulnerable species • Beam trawl: Total individuals/area Total biomass/area # Individuals per species and area Biomass per species and area Diversity Length frequency distribution of dominant and/or vulnerable species
Data Output	• Time series values for # of individuals, biomass, fish community composition, and species-specific length frequency • Presence absence of non-native species
Examples where this methodology has been used	Bundesamt für Seeschifffahrt Hydrographie 2007; CEFAS 2004

Fisheries Protocol X3a and X3b- Reef and Aggregation Effects

MONITORING OBJECTIVE: Monitor for changes in abundance or species composition of fish around renewable energy structures, including non-native species

	X3a: Depth of installation < 20 m	**X3b: Depth of installation > 20 m**
Indicator(s) of the impact	Increase in fish abundance overall or in some species; shift in species composition; increase in presence of non-native species	
Methodology or Technique to Collect Data	Video surveys with ROV	Visual surveys with SCUBA
Description of Methodology or Technique(s) for collecting data	• Minimum of four devices, four transects/device. • Seasonal surveys 4 times/year for 5 years • Transects of 1 km, radiating out from devices in four directions • Lasers for measuring length of fish species	• Minimum of four devices, four transects/device. • Transects 1-5 m and 20 m from devices on four sides • Transects radiating out from devices in four directions • Seasonal surveys 2 times/year for 3 years • Transects of 15-30 min duration • Estimation of species length by divers
Methodology for Analyzing data	ANOVA on # species, # of fish, multivariate analysis of fish community characteristics, multidimensional scaling, cluster analysis	ANOVA on # species, # of fish, multivariate analysis of fish community characteristics, multidimensional scaling, cluster analysis
Frequency and Duration	• 4 seasonal baseline surveys during pre-construction • Seasonal surveys 4 times/year for a minimum of 5 years during operation	• 2 baseline surveys during pre-construction (spring and fall) • Seasonal surveys 2 times/year for a minimum of 5 years during operation
Spatial Scale	Small to medium	Small
Other Considerations **(E.g. Advantages or Disadvantages)**	• Can be combined with reef effect protocol for benthic habitat • Accounts for seasonal and interannual variability	• Can be combined with reef effect protocol for benthic habitat • Accounts for seasonal and interannual variability
Relationship to Other Protocols	Can be combined with Fisheries Protocol X2 or Marine Mammal and Sea Turtle Protocols Z6-Z8 or Benthic Environment Monitoring Protocol W2	
Cost (High, Medium, Low)	Low (Annually, depending on the number of surveys)	Low
Data Format	• # Species per area • # Individuals per species and area • Change in species/individuals with distance from devices • Biomass per species and area	

	• Length frequency distribution of dominant and/or vulnerable species	
Data Output	• Time series values for # of species, # individuals • Biomass estimates • Presence absence of non-native species	
Examples where this methodology has been used	Rademacher and Render, 2003; Love et al. 1994.	Wilhelmsson et al. 2006.

Fisheries Protocol X4: Blade Strikes

MONITORING OBJECTIVE: Monitor for blade strikes from tidal energy devices

Indicator(s) of the impact	Observation of blade strike incidents
Methodology or Technique to Collect Data	Video or sonar surveys of tidal turbine
Description of Methodology or Technique(s) for collecting data	• Video cameras or DIDSON sonar system installed on a subset of turbines (3-5) • Video or Sonar will detect the movement of fish in the immediate vicinity of the tidal turbine • Video or Sonar will detect the number of fish approaching the turbine and the number of fish that pass through the blades, both while the turbines are operating and at periods of slack tide
Methodology for Analyzing data	• Observation of blade strikes • Observation of movements of fish through and around turbine and vicinity of fish to turbine blades
Frequency and Duration	Sonar installation will occur twice during the first year (spring and fall) for X days at a time
Spatial Scale	Subset of turbines (3-5) dispersed throughout turbine field
Other Considerations (E.g. Advantages or Disadvantages)	• One study (Verdant Power 2010) found the DIDSON system could not be continuously deployed because of biofouling and siltation. The system should be deployed for a set period of time and then removed. • The sonar system may not be useful for identifying fish at the species level. • Verdant Power (2010) found the DIDSON system useful where the water was too turbid for video monitoring; video monitoring may be more practical where turbidity is less. • DIDSON system was only effective at a distance of 15 m for appropriate resolution.
Relationship to Other Protocols	Can be combined with Avian Species Monitoring Protocol Y12 or Fisheries Protocol X2
Cost (High, Medium, Low)	Medium
Data Format	• Frequency of targets per time (fish within 10m, 5 m, 1 m of turbine; fish passing through turbine) • Distribution of fish in vicinity of turbine in various environmental conditions (tidal movement, slack tide, day/night) • Presence/absence of fish in the vicinity of the device • Number of observed blade strikes or fish passing through the devices per unit of time (at different times of day and in different seasons)

Data Output	• Video stills (extracted from video footage) • Sonar stills (extracted from sonar footage)
Examples where this methodology has been used	Verdant Power 2010.

Fisheries Protocol X5 – Spatial Use of Fishing Activity

MONITORING OBJECTIVE: Monitor for changes in the spatial distribution of fishing activity around a renewable energy installation

Protocol	X5a	X5b
Indicator(s) of the impact	Changes in numbers of vessels fishing near or inside of the renewable energy area (more or fewer vessels); change in the presence of fixed fishing gear (gillnets, pots, traps) inside of or around a renewable energy installation (more or less fixed gear)	
Methodology or Technique to Collect Data	VMS installed on vessels to track movements	Vessel surveys to count numbers of vessels fishing, fixed fishing gear in use
Description of Methodology or Technique(s) for collecting data	• VMS systems installed on a sizeable and representative subsample of fishing fleet (e.g. 25% of vessels) known to utilize area where renewable energy infrastructure being installed. • Analysis of VMS data from NMFS on vessels already installed with the device for the same time period. • Movements of vessels tracked for 2 years pre-construction, during construction, and minimum 5 years post-construction. • Tracking of movements with VMS should also take place in a control area with no development, to exclude effects of fish movements, environmental variables, etc.	• Transects with a boat to count numbers of fishing boats engaged in fishing inside and outside of renewable energy installation, including type of vessel, relative size of vessel, and type of fishing activity (type of gear; steaming, trawling, setting gear, etc.). • Transects with a boat to count numbers of fixed fishing gear, including gillnets, lobster traps, fish pots, etc. • Equal transects in a control area of equal size.
Methodology for Analyzing data	• GIS • Multidimensional scaling	• GIS • Multidimensional scaling
Frequency and Duration	• Year-round survey of vessel movement. • 2 years pre-construction, during construction, and minimum 3 years post-construction.	• Year-round survey of fixed fishing gear and vessel activity. • 2 years pre-construction, during construction, and minimum 3 years post-construction.
Spatial Scale	• Encompass entire renewable energy zone and large buffer area around renewable energy installation. • Equal transects in a control area of equal size.	• Encompass entire renewable energy zone and large buffer area around renewable energy installation. • Equal transects in a control area of equal size.
Other Considerations (E.g. Advantages or Disadvantages)	• Some vessels will already be installed with VMS and are reporting VMS to NMFS. Only certain fisheries or vessels over a certain size are	• This methodology will be less expensive than installing VMS systems (depending on the number of vessels/VMS systems to be installed).

	required to carry VMS systems. • VMS should be installed on a variety of types of fishing boats engaged in a wide variety of fisheries to analyze which fisheries are most affected by the renewable energy installation. • Analysis should be combined with analysis of trawl and fixed gear surveys from within and outside of renewable energy field. • Accounts for seasonal variability, and somewhat for interannual variability.	• The most appropriate methodology may depend on the important fisheries within the area. • When mobile fishing gear is predominant, VMS may be more suitable. When fixed fishing gear is predominant, transect surveys will be sufficient. • Transects may be able to be combined with those for marine mammals or birds • Analysis should be combined with analysis of trawl and fixed gear surveys from within and outside of renewable energy field. • Accounts for seasonal variability, and somewhat for interannual variability.
Relationship to Other Protocols	Can also be combined with Avian Species Monitoring Protocol Y1 and Marine Mammal and Sea Turtles Monitoring Protocol Z1	
Cost (High, Medium, Low)	Medium (Depending on the number of VMS units required)	Low
Data Format	• Vessels/area • Distribution of vessel types	
Data Output	Spatial Use Maps	
Examples where this methodology has been used	Wiley et al., 2003.	

8.6. Component Decision Tree for Avian Species

Determine which impacts to Avian Species need to be monitored:

The energy resource is

Wind……………………………………………………………………………………………………… Go to A

Waves…………………………………………………………………………………………………… Go to B

Tidal……………………………………………………………………………………………………… Go to C

A. The stage of the wind energy project is

Construction……………………………………………………………… Go to D

Operation…………………………………………………………………… Go to D, Go to E, Y8

Decommissioning………………………………………………………… Go to D

B. The stage of the tidal project is

Construction……………………………………………………………………………… Go to D

Operation…………………………………………………………………………………… Go to D, Y9

Decommissioning………………………………………………………………………… Go to D

C. The stage of the wave energy project is

Construction……………………………………………………………………………… Go to D

Operation…………………………………………………………………………… Go to D

Decommissioning………………………………………………………………………… Go to D

D. The target species are

Easily disturbed, cryptic…….. Y3, Y4

Easily disturbed, non-cryptic…………………………………………………….... Y2, Y3, Y4

Not easily disturbed, cryptic…………………………………………………… Y1, Y3, Y4

Not easily disturbed, non-cryptic………………………………….…………… Y1, Y2, Y3, Y4

E. The target species are

Diurnal…………………………..Y5, Y6

Nocturnal……………………….……………………………………………………….. Y5, Y7

Recommended protocols:

Y1. Ship-based visual surveys

Y2. Aerial surveys using human observers

Y3. Aerial surveys using high-definition videography

Y4. Aerial surveys using digital still photography

Y5. Radar surveys

Y6. Visual surveys

Y7. Flight call surveys

Y8. Remote detection system

Y9. Sonar and video technology

Y10. Radio telemetry*

Y11. Satellite telemetry*

Y12. GPS tracking*

*Additional monitoring protocols that are more experimental in design; not included in Component Decision Tree for Avian Species

8.7. MONITORING PROTOCOLS FOR AVIAN SPECIES

Avian Protocol Y1: Ship-based Visual Surveys

MONITORING OBJECTIVE: Assess changes in spatial distribution and abundance of marine birds*.

(Can also be applied for pre-siting baseline studies)

Indicator(s) of Impact	Spatially-explicit changes in density estimates.
Methodology or Technique to Collect Data	Ship-based line-transect surveys using at least two observers in a 20-100 m ship.
Description of Methodology or Technique(s) for Collecting Data	Line-transect distance sample technique (Camphuysen et al. 2004; See Appendix D).
Methodology for Analyzing data	• Before After Gradient (BAG) or Before After Control Impact (BACI) monitoring design. • Model-based analysis (See Petersen *et al.* 2011).
Frequency and Duration	• Minimum of three surveys per season (winter, spring, summer, and fall) to monitor different migratory species. • Baseline: Minimum of two years pre construction (could be <2 years if adequate historical baseline data exists). • Post-construction: Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	• Sites <5 km^2, a buffer[#] of at least 1 km around impact area. • Sites 5 km^2 – 10 km^2, a buffer of at least 2 km. • Sites >10 km^2, a buffer of at least 4 km. • [#]Not necessarily a symmetrical buffer depending on device and predicted environmental effects.
Other Considerations **(E.g. Advantages or Disadvantages)**	• High detection probabilities for most species of marine birds. • Ability to assess behavior of birds, such as active foraging. • Possible to collect other covariates simultaneously including: sea surface temperature, chlorophyll, salinity and bioacoustics data. • Ability to identify individuals to species for difficult to identify taxa (e.g., terns, alcids, loons, gulls). • Ability to determine age and/or gender for some species to model population dynamics. • If surveys prior to 2005 were ship-based surveys, then this method is directly comparable to archived data. • Can be conducted nearshore (<3miles from shore), assuming appropriate water depth. • Safety risk for crew members lower than aerial surveys. • Able to potentially survey other taxa including marine mammals and sea turtles

	simultaneously. • Not suitable for nocturnal migrants including many species of shorebirds (Charadriformes) and songbirds (Passeriformes). • Slow survey speed, thus relatively small areas can be surveyed within a day. • Sea state limitations (especially in winter when favorable conditions are limited) Not suitable for some disturbance-prone species (e.g., seaducks, loons). • May displace or attract species, resulting in biased density estimates. • Ships may not be allowed within some wind facilities making post-construction comparisons difficult. • Cannot be conducted in very shallow or rocky areas. • Glare/wind/waves can often affect detection probabilities. • Challenging in areas with strong tidal currents.
Relationship to Other Protocols	Can be conducted in combination with Marine Mammals and Sea Turtles Protocol Z1 and Fisheries Resources Protocol X1
Cost (High, Medium, Low)	Medium (Annually, depending on the number of surveys conducted and size of ship)
Data Format	• Spatially-explicit locations with an accuracy of ± 300 m. • Flock size and identification of most individuals to species. • Distance of individual or flock from transect centerline to model density estimates. • Behavior (foraging, resting based on location – either on the water or flying). • For birds in flight, flight direction and estimated flight altitude. • Environmental covariates (sea state, wind speed and wind direction), which can be used to reduce variance estimates of population sizes.
Data Output	Spatially-explicit density estimates (and associated variance) by species within and outside the development area.
Examples where this methodology has been used	Vanermen et al. 2010

*Marine birds suitable for these survey include loons (Gaviidae), grebes (Podicipedidae), tubenoses (Procellariidae, Hydrobatidae), pelicans and allies (Fregatidae, Pelecanidae, Phaethontidae, Sulidae), cormorants (Phalcrocoracidae), wading birds (Ardeidae), waterfowl (Anatidae), diurnal raptors (Accipitridae, Falconidae), phalaropes (*Phalaropus* spp.), gulls and allies (Laridae), terns (*Sterna* spp.), and alcids (Alcidae).

Avian Protocol Y2: Aerial Surveys using Human Observers

MONITORING OBJECTIVE: Assess changes in spatial distribution and abundance of marine birds*.

(Can also be applied for pre-siting baseline studies)

Indicator(s) of Impact	Spatially-explicit changes in density estimates.
Methodology or Technique to Collect Data	Aerial line-transect; Visual surveys by observers.
Description of Methodology or Technique(s) for Collecting Data	Line-transect Distance Sample Technique (Camphuysen et al. 2004; Appendix D) from a plane with at least two observers.
Methodology for Analyzing data	• Before After Gradient (BAG) or Before After Control Impact (BACI) monitoring design. • Model-based analysis (See Petersen *et al.* 2011).
Frequency and Duration	• Minimum of three surveys per season (winter, spring, summer, and fall) to monitor different migratory species. • Baseline: Minimum of two years pre construction (could be <2 years if adequate historical baseline data exists). • Post-construction: Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	• Sites <5 km^2, a buffer[#] of at least 1 km around impact area. • Sites 5 km^2 – 10 km^2, a buffer of at least 2 km. • Sites >10 km^2, a buffer of at least 4 km. • [#]Not necessarily a symmetrical buffer depending on device and predicted environmental effects.
Other Considerations **(E.g. Advantages or Disadvantages)**	• High detection probabilities for most species of marine birds. • Able to detect disturbance-prone species. • Able to potentially simultaneously survey marine mammals. • Large areas can be surveyed rapidly. • Not suitable for nocturnal migrants including many species of shorebirds (Charadriformes) and songbirds (Passeriformes). • Birds disturbed due to low flight altitude (generally after being recorded). • Some detections may be identified only to a species group. • Can underestimate abundance of cryptic species. • Some wind facilities may not allow flights post-construction. • Safety issue for low altitude flights compared to ship-based surveys. • Glare can often affect detection probabilities.
Relationship to Other Protocols	Can be conducted in combination with Marine Mammals & Sea Turtles Protocol Z1
Cost (High, Medium, Low)	Medium (Annually, depending on the number of surveys)

Data Format	Spatially-explicit locations with an accuracy of ± 100 m. Flock size and identification of some detections to species or species groups. Distance of individual or flock from transect centerline to model density estimates. Behavior (foraging, resting based on location – on water or flying). For birds in flight, flight direction and estimated flight altitude. Environmental covariates (sea state, wind speed and wind direction), which can be used to reduce variance estimates of population sizes.
Data Output	Spatially-explicit density estimates (and associated variance) by species or taxonomic groups within and outside the development area.
Examples where this methodology has been used	Petersen et al. 2011; Maclean et al. 2006

*Marine birds suitable for these survey include loons (Gaviidae), tubenoses (Procellariidae, Hydrobatidae), pelicans and allies (Fregatidae, Pelecanidae, Phaethontidae, Sulidae), cormorants (Phalcrocoracidae), wading birds (Ardeidae), waterfowl (Anatidae), gulls and allies (Laridae), terns (*Sterna* spp.), and alcids (Alcidae).

Avian Protocol Y3: Aerial Surveys using High Definition Videography

MONITORING OBJECTIVE: Assess changes in spatial distribution and abundance of marine birds*.

(Can also be applied for pre-siting baseline studies)

Indicator(s) of Impact	Spatially-explicit changes in density estimates.
Methodology or Technique to Collect Data	Aerial strip-transect surveys; High definition videography.
Description of Methodology or Technique(s) for Collecting Data	Strip-transect methodology (See Appendix D).
Methodology for Analyzing data	• Before After Gradient Before After Control Impact (BACI) monitoring design. • Model based analysis (See Petersen et al. 2011).
Frequency and Duration	• Minimum of three surveys seasonally. • Baseline: At least two years pre construction (maybe possible in <2 years if adequate historical baseline data exists). If year 1 and year 2 are very different years for certain particular common and abundant species then baseline surveys should be continued. • Post-construction: Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	• Sites <5 km^2, a buffer[#] of at least 1 km around impact area. • Sites 5 km^2 – 10 km^2, a buffer of at least 2 km. • Sites >10 km^2, a buffer of at least 4 km. • [#]Not necessarily a symmetrical buffer depending on device and predicted environmental effects.
Other Considerations (E.g. Advantages or Disadvantages)	• High detection probabilities for all marine birds. • High spatial resolution of detections when assessing fine-scale determinants of distribution. • Large area can be surveyed rapidly. • Flight elevation high enough to not disturb birds, thus able to sample disturbance prone species. • Safer than observer-based aerial surveys that fly at lower altitudes. • More aircraft are potentially suitable for videography, as they do not have to be high winged aircraft. However, aircraft conversion may restrict utility (see Y4). • Permanent record of observations that could be reviewed by biologists in the future. • Spatially-explicit density estimates. • Potentially feasible to estimate of flight altitude of individuals or flocks. • Potentially able to survey marine mammals and sea turtles simultaneously. • Not suitable for nocturnal migrants such shorebirds (Charadriiformes) and songbirds (Passeriformes). • Technology is still evolving, particularly automation of processing and speed (see

	Y4). • Similar species may not be identifiable depending on imagery.
Relationship to Other Protocols	Can be conducted in combination with Marine Mammals & Sea Turtles Protocol Z1, and Fisheries Resources Protocol X1
Cost (High, Medium, Low)	High (Annually, depending on number of surveys)
Data Format	Flock size and identification of some detections to species or species groups (e.g. alcids). Distance of individual or flock from transect centerline to model density estimates. Behavior (foraging, resting based on location – on water or flying). Environmental covariates (sea state, wind speed and wind direction).
Data output	Spatially-explicit density estimates (and associated variance) by species or taxonomic groups within and outside the development area. Spatially-explicit density estimates of individuals or flocks to within 100 m of actual locations.
Examples where this methodology has been used	Mellor et al. 2007; Mellor and Maher 2008; Buckland et al. 2012

*Marine birds suitable for these survey include loons (Gaviidae), grebes (Podicipedidae), tubenoses (Procellariidae, Hydrobatidae), pelicans and allies (Fregatidae, Pelecanidae, Phaethontidae, Sulidae), cormorants (Phalcrocoracidae), wading birds (Ardeidae), waterfowl (Anatidae), diurnal raptors (Accipitridae, Falconidae), phalaropes (*Phalaropus* spp.), gulls and allies (Laridae), terns (*Sterna* spp.), and alcids (Alcidae).

Avian Protocol Y4: Aerial Surveys using Digital Still Photography

MONITORING OBJECTIVE: Assess changes in spatial distribution and abundance of marine birds*.

(Can also be applied for pre-siting baseline studies)

Indicator(s) of Impact	Spatially-explicit changes in density estimates.
Methodology or Technique to Collect Data	Aerial strip-transect surveys: Digital still photography.
Description of Methodology or Technique(s) for Collecting Data	Strip-transect methodology (See Appendix D).
Methodology for Analyzing data	• Before After Gradient monitoring design. • Model based analysis (See Petersen et al. 2011).
Frequency and Duration	• Minimum of three surveys seasonally. • Baseline: At least two years pre construction (maybe possible in <2 years if adequate historical baseline data exists). If year 1 and year 2 are very different years for certain particular common and abundant species then baseline surveys should be continued. • Post-construction: Recommended for up to 15 years post construction in years 1, 2, 3, 5, 10 and 15.
Spatial Scale	• Sites <5 km^2, a buffer# of at least 1 km around impact area. • Sites 5 km^2 – 10 km^2, a buffer of at least 2 km. • Sites >10 km^2, a buffer of at least 4 km. • #Not necessarily a symmetrical buffer depending on device and predicted environmental effects.
Other Considerations **(E.g. Advantages or Disadvantages)**	• High detection probabilities for most marine birds depending on image quality. • Large study areas can be surveyed rapidly. • Due to high flight altitude, able to survey disturbance-prone species. • Safer than observer-based aerial surveys that fly at lower altitudes. • More aircraft are potentially suitable for videography, as they do not have to be high winged aircraft, although modification can affect utility. • Permanent record of observations that could be reviewed by biologists in the future. • Accurate spatially-explicit density estimates. • Potentially estimate of flight altitude of individuals or flocks. • Able to survey marine mammals and sea turtles simultaneously. • Not suitable for nocturnal migrants such as plovers, sandpipers, and songbirds (Passeriformes). • Technology is still evolving. • Similar species may not be identifiable.
Relationship to Other Protocols	Can be conducted in combination with Marine Mammals & Sea Turtles Protocol Z1, and Fisheries Resources Protocol X1

Cost (High, Medium, Low)	High (Annually, depending on the number of surveys)
Data Format	• Flock size and identification of some detections to species or species groups. • Distance of individual or flock from transect centerline to model density estimates. • Behavior (foraging, resting based on location – on water or flying). • Environmental covariates (sea state, wind speed and wind direction).
Data output	• Spatially-explicit density estimates (and associated variance) by species or taxonomic groups within and outside the development area. • Spatially-explicit density estimates of individuals or flocks to within 100 m of actual locations.
Examples where this methodology has been used	Buckland et al. 2012

*Marine birds suitable for these survey include loons (Gaviidae), grebes (Podicipedidae), tubenoses (Procellariidae, Hydrobatidae), pelicans and allies (Fregatidae, Pelecanidae, Phaethontidae, Sulidae), cormorants (Phalcrocoracidae), wading birds (Ardeidae), waterfowl (Anatidae), diurnal raptors (Accipitridae, Falconidae), phalaropes (*Phalaropus* spp.), gulls and allies (Laridae), terns (*Sterna* spp.), and alcids (Alcidae).

Avian Protocol Y5: Radar Surveys

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	Marine Radar Surveys.
Description of Methodology or Technique(s) for Collecting Data	• Marine Radar: X-band for vertical radar; either X-Band or S-band for horizontal radar. • Minimum of 25kW recommended and a vertical beam width of 20 degrees to 25 degrees and a horizontal beam of 0.9 degrees and a transmission frequency of about 9.4GHz (x-band radar). • Standard operating range should be 1.5 km for vertical and 3 km for horizontal radar. • Sea state <5.
Methodology for Analyzing data	A Before-After design would provide information on changes in movement patterns (Desholm and Kahlert 2005)
Frequency and Duration	• Baseline: 1-2 years pre-construction • 1-2 years post construction. • Continuous 24-hour monitoring
Spatial Scale	• Sites <5 km^2, a buffer of at least 1 km around impact area. • Sites 5 km^2 – 10 km^2, a buffer of at least 2 km.
Other Considerations **(E.g. Advantages or Disadvantages)**	• During pre-construction monitoring, assessment of 3D traffic through wind facility airspace allows modeling of potential collision risk. • Strong contribution to EIS process and post-construction monitoring. • 3D light trajectories can be stored in GIS for comparison during the post-construction period. • Provides quantitative data on both diurnal and nocturnal movements, which few techniques allow. • Quantitative estimates of number of targets passing an area. • Flight speed can be used to group echoes to differentiate groups of birds (Smaller birds fly slower than larger birds). • Weather covariates can be collected simultaneously to investigate relationships with migration patterns. • Quantitative, accurate information on flight altitudes. Could be combined with ground truthing to make detections species specific. • Generally not capable of categorizing targets to species or species groups (e.g. seaducks), although diurnal ground-truthing can be used to assist species identification. • Algorithms to analyze raw radar data are often proprietary and not directly comparable among studies. • For offshore developments, requires a stable platform for the radar unit, which can be challenging. • Wave and sea clutter can be challenging to deal with depending on the platform

	mounting and equipment. • X-band radar more susceptible to rain clutter. • Can be challenging to develop precise quantitative counts due to issues with detection probabilities.
Cost (High, Medium, Low)	High (Annually, due to need for stable platform).
Data Format	Number of targets per hour by area and specific travel routes (3D).
Data Output	• Altitude distributions (100m increments up to 1000m). • Map of radar tracks (pre and post construction). For ground-truthed data, could provide some species-specific information. • Phenology of movements (number of targets, flight directions, and flight altitude).
Examples where this methodology has been used	Krijgsveld et al. 2010; Desholm et al. 2004.

Avian Protocol Y6: Visual Surveys of Flight Ecology

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	Visual Surveys
Description of Methodology or Technique(s) for Collecting Data	• Visual observations to assess movements of individual birds. • If conducted in conjunction with active radar, can be used to assess species-specific data. • Use range finding equipment that measures angles to gather flight trajectory data of individuals in 3D space. • Observations conducted from a stable platform near radar unit where targets can be seen prior to entering buffer surrounding wind farm. • Communication recommended between observer and radar operator in appropriate.
Methodology for Analyzing data	See Desholm and Kahlert 2005.
Frequency and Duration	• Surveys should take place during peak migration periods of target species. • This study could be conducted either pre- or post-construction (see Desholm and Kahlert 2005). • 1-2 years pre construction/1-2 years post construction?
Spatial Scale	• Seawatches generally detect movements of birds within 1 mile of observers. • Depends on if X- or S-band radar is used, but generally within 1-3 km of radar unit.
Other Considerations **(E.g. Advantages or Disadvantages)**	• Species-specific 3D flight trajectories through study area. • Allows identification of radar targets to species level, but only for larger diurnal migrants. • Collected data could potentially be used to assess changes in flight ecology of target species following construction. • Dependent on stable platforms for observations, thus either near land or from a jackup barge (which will be very expensive) • Not feasible for nocturnal targets or other low visibility conditions Detection probabilities are uncertain, but vary by size of targets. Most useful for larger species (crow-sized and larger). • Working on offshore platforms can be dangerous.
Cost (High, Medium, Low)	Low (Annually) for observers in coastal sites
Data Format	Species-specific information on flocks or individuals recorded.
Data Output	Flight intensities (i.e., targets per hour) and flight altitude of target species.
Examples where this methodology has been used	Krijgsveld et al. 2010

Avian Protocol Y7: Flight Call Surveys

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites.

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	Flight Call Surveys
Description of Methodology or Technique(s) for Collecting Data	• Acoustic observations of flight calls to determine species composition of birds detected by radar during nocturnal surveys. • Can be used in conjunction with an active radar survey to determine to species birds flying through the study area. • Observations conducted from a stable platform where individuals or flocks can be heard prior to entering buffer surrounding wind farm. • Communication recommended between observer and radar operator if appropriate.
Methodology for Analyzing data	Before – After – Control - Impact.
Frequency and Duration	• Surveys should take place during peak migration periods of target species. • At least one year pre-construction and one year post-construction.
Spatial Scale	Encompassing development area plus a buffer.
Other Considerations (E.g. Advantages or Disadvantages)	• Only way to identify radar targets to species at night. • Primarily useful for passerines. • Uncertainty about detection probabilities for calling targets. Some species do not call under certain circumstances making it difficult for before/after comparisons. • Working on offshore platforms can be costly and potentially hazardous.
Cost (High, Medium, Low)	Medium (Annually, due to working on offshore platform)
Data Format	• Identification of radar targets to species. • If coupled with a radar study, can be used to determine species detected on the radar (for individuals that call).
Data Output	Relative flight call intensities (i.e., calls per hour by species).
Examples where this methodology has been used	Krijgsveld et al. 2010

Avian Protocol Y8: Systems to Remotely Assess Collision Risk

MONITORING OBJECTIVE: Assess direct mortality (above-water collision) of marine birds.

Indicator(s) of Impact	Birds documented striking infrastructure resulting in death or injury.
Methodology or Technique to Collect Data	• Thermal Animal Detection System (TADS) • Infrared cameras • Emerging technologies
Description of Methodology or Technique(s) for collecting data	• Thermal cameras use the heat radiating off of birds to create a thermal image. • Operation should be limited to 1-2 km due to the low optical resolution of the thermal camera. • Video cameras could be trained on wind turbines to record diurnal collision rates.
Monitoring Design and Analysis Recommendations	Minimum of one TAD per wind facility with a maximum of 1 TAD per wind turbine.
Frequency and Duration	24 hours per day/ 7 days per week for an entire year. One to two years post construction.
Spatial Scale	Individual wind turbines.
Other Considerations (E.g. Advantages or Disadvantages)	• Ability to remotely monitor collision risk 24 hours per day, 7 days per week. • Can detect nocturnal targets including bats. • Low optical resolution makes identifying to species difficult. • Difficult in harsh offshore conditions. • Uncertainty of effectiveness in inclement weather. • Little research has been conducted using these approaches, thus there needs to be a great deal of research to develop these types of technologies.
Cost (High, Medium, Low)	Low (Annually, depending on how many TADS are put in place
Data Format	Number of targets approaching and colliding with turbines.
Data Output	Total number of targets and collisions near wind facility, including a time stamp.
Examples where this methodology has been used	Walls et al. 2009; Desholm et al. 2004; Desholm et al. 2006.

Avian Protocol Y9: Sonar and Video Technology

MONITORING OBJECTIVE: Assess direct mortality (under water-collision) of marine birds.

Indicator(s) of Impact	Birds documented striking infrastructure resulting in death or injury.
Methodology or Technique to Collect Data	• Point count could be used to monitor avian use of project area from surface. • Currently, no remote technologies developed to detect underwater avian collisions (sonar and video technology developed for demersal fish strikes may work for birds).
Description of Methodology or Technique(s) for Collecting Data	Station observers to visually monitor the project area to determine if diving birds are using the project area.
Monitoring Design and Analysis Recommendations	Post-construction surveys.
Frequency and Duration	• Weekly during time period when diving birds could be in study area. • One year post-construction.
Spatial Scale	Project area.
Other Considerations (E.g. Advantages or Disadvantages)	• Allow quick determination if potentially vulnerable species (diving birds) are using the study area. • Cost effective compared to other potential strategies. • Practical only on days when observers could be stationed at project area • Only feasible for diurnal observations. • Best for larger marine birds with high detection probabilities.
Cost (High, Medium, Low)	Medium (Annually)
Relationship to Other Protocols	Can be conducted in combination with Fisheries Resources Protocol X4
Data Format	Number of individuals of target species detected in study area.
Data Output	Number of vulnerable targets (diving birds) in study area.

Examples where this methodology has been used	None to our knowledge

Avian Protocol Y10: Using Radio Telemetry to Assess Movements*

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	Radio tracking of select target species.
Description of Methodology or Technique(s) for Collecting Data	• Radio tracking using VHF or nanotags • Best for short-range tracking (<25km). • Can be used to correct for availability bias in line transect or strip transect abundance surveys.
Methodology for Analyzing data	Depends on movement ecology of target species.
Frequency and Duration	• If focused on birds from nearby breeding colony, throughout breeding season. • Depends on biology of target species and battery life of transmitters.
Spatial Scale	Depends on biology of target species and range of transmitters and receiving stations.
Other Considerations **(E.g. Advantages or Disadvantages)**	• A network of receiving stations could potentially track movements of target species throughout a region. • Could be used to track movements of nocturnal and diurnal migrants. • Nanotags have the ability to track movements of small birds (e.g., passerines) and bats. • Potential to accurately assess the position of individuals. • Low sample size may not represent larger population. • Absence of target individuals in the developed area does not necessarily mean that the population is not using the area. • Trade-off between battery life and data collection. • Data collection can be intensive with multiple observers (or boats) needed. • Receiving stations general can detect transmitters within 10-20 km of station.
Cost (High, Medium, Low)	Medium (Annually depending on number of individuals tracked and their locations)
Data Format	Real time locations of target species
Data Output	Phenology of spatially-explicit movements of target species.
Examples where this methodology has been used	Perrow et al. 2006; Walls et al. 2009.

Avian Protocol Y11: Using Satellite Telemetry to Assess Movements*

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites.

Indicator(s) of Impact	Changes in flight paths of foraging, commuting, or migrating birds within development area.
Methodology or Technique to Collect Data	Satellite tracking.
Description of Methodology or Technique(s) for Collecting Data	• Position of individual is estimated on each satellite pass. • Accurate to 250m, but can be variable in accuracy. • Number of locations per day depends on programmed duty cycle and latitude/longitude. • Observers not required to track birds. • Can be used to correct for availability bias in line transect or strip transect abundance surveys.
Methodology for Analyzing data	Home range analysis.
Frequency and Duration	• Variable duty cycles can make transmitters last from 6 month to 2 years, depending on how often tag is turned on. Current recommendations suggest tags should be on for at least 4 hours to increase the probability of accurate fixes. • Depends on biology of target species.
Spatial Scale	Encompassing development area plus a buffer.
Other Considerations **(E.g. Advantages or Disadvantages)**	• In the UK, this technology has been used to assess movements of migratory birds through the impact area, although birds may breed and winter in areas outside of the impact area. • Ideal for general studies of long-distance movements. Able to track movements over 1000s of kilometers. • Birds can be tracked in variable weather conditions. • Accurate location data of individuals. • Information on habitat preferences and larger scale movements. • More suited for large scale movements, not useful for fine-scale movements. • Depending on target species, transmitters might have to be surgically implanted, which means hiring a veterinarian for this procedure and there is a risk of losing the bird. • Generally only about 700 fixes per battery cycle. • Low sample size may not represent larger population. • Absence of target individuals in the developed area does not necessarily mean that the population is not using the area. • Given current available transmitters, unsuitable for species that weight less than approx. 400 grams because current recommendations suggest that tags should not be more than 3% of body mass and the current smallest tags are about 12 g. • Trade-off between battery life and data collection.

Cost (High, Medium, Low)	Low (Annually, depending on number of individuals tracked)
Data Format	Spatially-explicit location data, accurate to within 250 m of actual bird's location, with a time stamp accurate to the nearest second.
Data Output	Spatially-explicit location data can be as accurate to within 250 m of actual bird's location.
Examples where this methodology has been used	Griffin et al. 2010; Walls et al. 2009.

Avian Protocol Y12: Using GPS tracking to Assess Movements*

MONITORING OBJECTIVE: Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites.

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	GPS tracking.
Description of Methodology or Technique(s) for collecting data	• Accurate to within ±5m • Some technologies require birds to be recaptured to upload data. • Works best on colony-breeding birds that can be easily recaptured.
Methodology for Analyzing data	Before-After design, home range analysis.
Frequency and Duration	Depends on biology of target species.
Spatial Scale	Not relevant.
Other Considerations (E.g. Advantages or Disadvantages)	• Extremely accurate location data of individuals compared other technologies. • Can track a bird for over one year, with thousands of fixes during this annual cycle. • Information on habitat preferences and movement. • Low sample size may not represent larger population. • Absence of target individuals in the developed area does not necessarily mean that the population is not using the area. • Mass of available tags makes this technology unsuitable for species less than 400 g, as current GPS technologies go down to 12 g. • Current devices cannot be implanted; however, newer loggers can store up to one year of data that can be downloaded using a variety of technologies. • Studies have shown that tags should not be more than 3% of body mass. • Trade-off between battery life and data collection.
Cost (High, Medium, Low)	Low (Annually, depending on number of individuals tracked)
Data Format	Real time locations, accurate to < 5 m to nearest minute.
Data output	Spatially-explicit location data, can be as accurate to within 5 m of actual bird's location.
Examples where this methodology has been used	Walls et al. 2009.

*Additional monitoring protocols that are more experimental in design; not included in Component Decision Tree for Avian Species

8.8. Component Decision Tree for Marine Mammals

Determine which effects to Marine Mammals need to be monitored:

The energy resource is

Wind………………………………………………………………………………………… Go to A

Tidal………………………………………………………………………………………… Go to B

Waves……………………………………………………………………………………… Go to C

A. The stage of the wind energy project is

Construction…………………………………………………………… Z1, Z2, Z3, Z4, Z5

Operation………………………………………………………………… Z1, Z2, Z3, Z4, Z5

Decommissioning……………………………………………………… Z1, Z2, Z3, Z4, Z5

B. The stage of the tidal energy project is

Construction…………………………………………………………… Z1, Z2, Z3, Z4, Z5

Operation………………………………………………………………… Z1, Z2, Z3, Z4, Z5

Decommissioning……………………………………………………… Z1, Z2, Z3, Z4, Z5

C. The stage of the wave energy project is

Construction…………………………………………………………… Z1, Z2, Z3, Z4, Z5

Operation………………………………………………………………… Z1, Z2, Z3, Z4, Z5

Decommissioning……………………………………………………… Z1, Z2, Z3, Z4, Z5

Recommended protocols:

Z1. Visual surveys

Z2. Passive acoustic monitoring

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Z6. Underwater photography

Z7. SCUBA surveys

Z8. ROV surveys

8.9. Component Decision Tree for Sea Turtles

Determine which effects to Sea Turtles need to be monitored:

The energy resource is

Wind……………………………………………………………………………………………Go to A

Tidal……………………………………………………………………………………………Go to B

Waves…………………………………………………………………………………………Go to C

A. The wind turbine foundation is

Monopile OR Tripod OR Floating mooring…………………………………… Go to A1

Lattice OR Gravity ………………………………………………………… Go to A2

A1. The stage of the monopile or tripod or floating mooring wind turbine project is

Construction……………………………………………………Z1, Z3, Z4, Z5, Z8

Operation…………………………………………………………… Z1, Z3, Z4, Z5

Decommissioning………………………………………………Z1, Z3, Z4, Z5, Z8

A2. The stage of the lattice structure or gravity foundation wind project is

Construction…………………………………………Z1, Z3, Z4, Z5, Z8

Operation……………………………………………… Z1, WZ, Z4, Z5

Decommissioning……………………………………Z1, Z3, Z4, Z5, Z6, Z7, Z8

B. The tidal turbine type is

Open OR shrouded bottom-mounted……………………………………… Go to B1

Open OR shrouded floating mooring……………………………………… Go to B2

B1. The stage of the bottom-mounted tidal turbine project is

Construction…..……….……….. Z1, Z3, Z4, Z5, Z8

Operation…..……………………...Z1, Z3, Z4, Z5

Decommissioning…………………………….................................Z1, Z3, Z4, Z5, Z6, Z7, Z8

B2. The stage of the floating mooring tidal turbine project is

Construction…..……….………..Z1, Z3, Z4, Z5, Z8

Operation…..……………………..Z1, Z3, Z4, Z5

Decommissioning…………………………... Z1, Z3 Z4, Z5, Z8

C. The stage of the wave energy device is

Construction..………..………...Z1, Z3, Z4, Z5, Z8

Operation………………...………... Z1, Z3, Z4, Z5

Decommissioning………………………….. Z1, Z3, Z4, Z5, Z8

Recommended protocols:

Z1. Visual surveys

Z2. Passive acoustic monitoring

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Z6. Underwater photography

Z7. SCUBA surveys

Z8. ROV surveys

8.10. MONITORING PROTOCOLS FOR MARINE MAMMALS AND/OR SEA TURTLES

Marine Mammals & Sea Turtles Protocol Z1: Visual surveys

(Can also be applied for pre-siting baseline studies)

MONITORING OBJECTIVE(S):

Construction Noise (pile driving)/Decommissioning Noise (pile removal, explosives): Mortality, injury, or disturbance of marine mammals or sea turtles by loud sounds
Operational Noise: Disturbance
Vessel Collisions: Mortality or injury
Entanglements: Mortality or injury
Cable-laying: Disturbance, mortality or injury

Indicator(s) of the impact	Changes in local or regional distribution, abundance, or behavior; Presence of dead or injured animals.
Methodology or Technique to Collect Data	Ship-based or aerial visual surveys
Description of Methodology or Technique(s) to Collect Data	• Visual surveys entail searching by trained observers for target species. • Typically observers are aboard ships and/or aircraft following pre-defined track-lines covering an area of interest, but surveys can be land-based for a specific focus (turtle nesting, pinniped rookeries or haul-outs). • Survey methodology can encompass higher-tech options, e.g., high-definition photography or videography. • Surveys also can secondarily provide data for mitigation, e.g., providing advance warning of animals nearby or approaching an impact zone. (See Appendix E for more detailed descriptions)
Methodology for Analyzing data	• Line-transect or strip-transect analysis of survey data, using well-established methods, results in estimates of the density (and therefore abundance) of mammal and turtle species within the study area. • Since the range of each species is generally much larger than the scale of any given ORED project, the scope of these surveys will be too small to estimate population abundance. • There should also be Before-After-Control-Impact (BACI) analysis on geospatial data given an appropriate sampling design.
Frequency and Duration	• At least 2 years prior to beginning construction, with the exact duration partially site-specific depending on the extent of prior sampling. • Sampling should continue for the full duration of construction, and at least 2-3 years post-construction. • Survey frequency will be project-specific depending on the species present and their densities (rare species require more sampling to generate robust estimates).
Spatial Scale	• The minimum scale would be the project area plus some buffer. • For noise impacts, an acoustic propagation model will predict the maximum ranges of potential acoustic injury or disturbance; that will determine the minimum extent of the "impact" area for a survey. • For effective BACI analysis, the "control" area should be beyond those

	ranges, but in an ecologically equivalent habitat with similar species and densities present.
Other Considerations **(E.g. Advantages or Disadvantages)**	• Visual surveys only work well where population densities are sufficiently high to produce necessary sample sizes and statistically robust estimates; their use is also limited at night or under reduced visibility conditions (fog, high winds, storms). • Inter-annual variability in marine mammal and sea turtle populations is known to be high, and the duration of construction of any ORED facility will be much shorter than that variability. • A well-designed BACI study with appropriate control and impact areas might be able to account for effects of variability in both habitat and population characteristics.
Relationship to other protocols	Survey data can provide ground-truthing (confirmation of species IDs) for passive-acoustic monitoring (Protocol Z2). Surveys can alert MMOs to animal presence (Protocol Z3), or pass on observations of dead or injured animals to stranding responders for recovery and necropsy (Protocol Z4).
Cost (High, Medium, Low)	Medium to High (Annually)
Data Format	There is a variety of existing formats for aerial or shipboard survey data, but they are effectively interchangeable if the necessary data fields are collected in the first place (Kenney, 2001, 2010; Halpin et al., 2009). The data collection and management methodology is sufficiently well-established so that any organization capable of fielding a survey effort is already familiar with data formats. Any additional standardization required can easily be established.
Data Output	From the raw survey data, three basic types of data output are possible (see Kenney and Shoop, 2012, for a summary of aerial survey methods). At the most basic are geospatial data—sighting locations that can be mapped in GIS or summarized for statistical analysis. At the most rigorous level, estimates of species density can be computed using line-transect or strip-transect methodology, assuming that there are sufficient sightings of that species to generate the necessary sighting probability models. At the intermediate level of statistical rigor, it can be possible to develop relative abundance estimates (see Kenney and Vigness-Raposa, 2010 for an example).
Examples where this methodology has been used	CETAP 1982; Waring et al., 2010; Allen and Angliss, 2011; Caretta et al., 2011; Forney, 2000; Ferguson et al., 2006a, 2006b; Redfern et al., 2006; Barlow et al., 2009; Becker et al., 2010; Teilmann et al., 2006a, 2006b; Thompson et al., 2010; Edrén et al., 2010; Malme et al., 1984; Frankel and Clark, 1998 (See Appendix E)

Marine Mammals & Sea Turtles Protocol Z2: Passive Acoustic Monitoring

(Can also be applied for pre-siting baseline studies)

MONITORING OBJECTIVE(S):

Construction Noise (pile driving)/Decommissioning Noise (pile removal, explosives): Disturbance of marine mammals by loud sounds
Operational Noise: Disturbance; Changes in distribution or abundance
Vessel Traffic: Disturbance; Changes in distribution or abundance
Cable-laying: Disturbance; Changes in distribution or abundance

Indicator(s) of the impact	Changes in distribution, abundance, or behavior.
Methodology or Technique to Collect Data	Passive Acoustic Monitoring
Description of Methodology or Technique(s) to Collect Data	• Passive acoustic monitoring essentially involves listening to ambient sounds and identifying vocalizations produced by marine mammals. • Used for assessing the distribution, relative abundance, and behavior of animals in the study area. • Can be used to monitor noise from the activity. • Either records sounds directly or archives summary data on species detections. • Can include bottom-mounted hydrophone arrays, anchored moorings, hydrophones or hydrophone arrays towed behind vessels, or expendable sonobuoys deployed from aircraft or ships. (See Appendix E for more details)
Methodology for Analyzing data	BACI analysis on a variety of data metrics.
Frequency and Duration	• Baseline: at least 2 years prior to beginning construction, with the exact duration partially site-specific depending on the extent of prior sampling. • Sampling should continue for the full duration of construction, and at least 2-3 years post-construction.
Spatial Scale	• For noise impacts, an acoustic propagation model will predict the maximum ranges of potential acoustic injury or disturbance; that will determine the minimum extent of the "impact" area for a survey. • For effective BACI analysis, the "control" area should be beyond those ranges, but in an ecologically equivalent habitat with similar species and densities present. • Cost considerations will factor in to decisions on the number of sensors that can be deployed.
Other Considerations **(E.g. Advantages or Disadvantages)**	• PAM only works on species that routinely vocalize (i.e., not on seals or sea turtles). • Autonomous sensors that must be recovered to download the data provide no real-time monitoring capability. • Because of limitations on data uplink bandwidth, typical near-real-time sensors provide only detections of pre-programmed species (usually right whales) and not multi-species data or continuous data.

	• Inter-annual variability in marine mammal and sea turtle populations is known to be high, and the duration of construction of any ORED facility will be much shorter than that variability. • A well-designed BACI study with appropriate control and impact areas might be able to account for effects of variability in both habitat and population characteristics.
Relationship to other protocols	Data can complement other MM&ST protocols.
Cost (High, Medium, Low)	Medium to High (Annually)
Data Format	The data output from passive-acoustic monitoring will depend heavily on the sensors and sampling methodology employed (See Appendix E)
Data Output	• Continuous data can be analyzed for all species that might be present and whose vocalizations fall within the frequency range recorded. • Actual tracks of vocalizing individuals can be compared between control and impact areas or times. • Combined visual data from shipboard surveys and simultaneous PAM data from towed arrays can be used to derive density estimates • Porpoise-positive minutes (minutes with clicks recorded), waiting time between encounters (detections of sets of clicks), waiting time from the end of pile-driving to the first detection, duration of encounters, and number of clicks per porpoise-positive minute (e.g., Carstensen et al., 2006; Teilmann et al., 2006a; Tougaard et al., 2009).
Examples where this methodology has been used	Carstensen et al., 2006; Teilmann et al., 2006a, 2008; Diederichs et al., 2008; Tougaard et al., 2009; Clausen et al., 2010; Brandt et al., 2011; Tyack et al., 2011; NMFS, 2010b, 2010c; Risch et al., 2012 (see Appendix E)

Marine Mammals & Sea Turtles Protocol Z3: Marine Mammal Observers (MMOs)

MONITORING OBJECTIVE(S):

Construction Noise (pile driving)/Decommissioning Noise (pile removal, explosives): Mortality, injury, or disturbance of marine mammals or sea turtles
Vessel Traffic: Mortality, injury, or disturbance of marine mammals or sea turtles
Cable-laying: Mortality, injury, or disturbance of marine mammals or sea turtles
Entanglement: Mortality or injury of marine mammals or sea turtles

Indicator(s) of the impact	Presence of dead or injured animals; detection of animals within impact zones of potentially harmful activities.
Methodology or Technique to Collect Data	Marine Mammal Observers used in construction and operation areas
Description of Methodology or Technique(s) to Collect Data	• Marine Mammal (or Protected Species) Observers are trained observers posted on board vessels in an active construction or operational area. • The primary objective of an MMO program often is mitigation—detection of animals in potential zones of injury and shutting down operation and/or stopping or diverting vessels. • MMOs can scan for animals using the naked eye or highpowered binoculars, depending on the platform. (See Appendix E for more details)
Methodology for Analyzing data	Given the primary mitigation objective, data analysis is generally minimal, e.g., nothing beyond a list of animals observed within given ranges of the activity being monitored and any observed behavioral reactions.
Frequency and Duration	MMOs should be deployed continuously for the full duration of construction, as well as on board vessels where the risk of impacts is high, which is project-specific.
Spatial Scale	Limited to the visual range of an observer or the binoculars.
Other Considerations **(E.g. Advantages or Disadvantages)**	MMO effectiveness is limited by visibility and distance. For example, noise disturbance from pile-driving is possible beyond the distance where an MMO posted near the construction site might see an animal.
Relationship to other protocols	Data from visual and real-time passive acoustic surveys (Protocols Z1 and Z2) can alert MMOs to animals near or approaching the impact zone.
Cost (High, Medium, Low)	Low
Data Format	• Standard sighting data (date, time, location, species, numbers, behaviors), which can be added to datasets from any survey programs • Behavioral observations can also be used to assess potential negative effects of project activities on behavior.
Data Output	Simple summaries.
Examples where this methodology has been used	MMS, 2009; NMFS, 2003; NMFS, 2010a; DON, 2009 (See also Appendix E)

Marine Mammals & Sea Turtles Protocol Z4: Stranding Response Networks

MONITORING OBJECTIVE(S):

Construction Noise (pile driving)/Decommissioning Noise (pile removal, explosives): Mortality or injury of marine mammals or sea turtles
Vessel Traffic: Mortality or injury of marine mammals or sea turtles
Cable-laying: Mortality or injury of marine mammals or sea turtles
Entanglement: Mortality or injury of marine mammals or sea turtles

Indicator(s) of the impact	Detection of dead or injured animals with evidence of causation from impacts of the project.
Methodology or Technique to Collect Data	Data collection from marine mammal stranding response networks
Description of Methodology or Technique(s) to Collect Data	• There are regional stranding response networks presently in operation along all coasts of the U.S. • There should be enhanced stranding investigational response in areas of potential or on-going development that might detect injuries caused by construction or other activities. • This would include support for recovering floating carcasses detected by monitoring surveys or MMOs, and for detailed necropsies and pathology studies of all stranded or recovered carcasses where there is any evidence for the mortality to have been related to the MRE project. • Given sufficient standardization of response and data collection, a BACI analysis of stranding data could be possible. (See Appendix E for more details)
Methodology for Analyzing data	Standard veterinary pathology methods.
Frequency and Duration	Continuous for the duration of the project.
Spatial Scale	Coast-wide with enhanced response in regions where ORED facilities are planned, under construction, or in operation.
Other Considerations **(E.g. Advantages or Disadvantages)**	• Stranding networks are already in place and would require only enhancement to be effective for monitoring purposes. • Determining the cause of death can be very difficult and in some cases impossible, depending on the condition of the carcass and skill level of the person making the determination.
Relationship to other protocols	Data feed into other MM&ST protocols.
Cost (High, Medium, Low)	Low
Data Format	Not Applicable.
Data Output	Cause-of-death determinations for all marine mammals or sea turtles found dead in the vicinity of ORED facilities, based on standard veterinary necropsy and pathology methods

Examples where this methodology has been used	Waring et al., 2010; Allen and Angliss, 2011; Caretta et al., 2011 (See Appendix E)

Marine Mammals & Sea Turtles Protocol Z5: Tagging

MONITORING OBJECTIVE: Detection of disturbance of marine mammals or sea turtles by noise, activities, or structures from ORED

Indicator(s) of the impact	Detection of changes in fine-scale distribution, movement, or behavior of individuals.
Methodology or Technique to Collect Data	Tagging of marine mammals or sea turtles to track location and movement
Description of Methodology or Technique(s) to Collect Data	Tagging involves fixing a device to an individual animal and then tracking the location of that individual, often recording other data parameters simultaneously. (See Appendix E for more details)
Methodology for Analyzing data	• Highly dependent on the type of tag used. • BACI or impact gradient analysis on geospatial data and/or behavioral data can be possible—assuming sufficient sample sizes and that the tagged animals cooperate by utilizing an appropriate selection of habitat sites.
Frequency and Duration	Species- and project-specific; a power analysis would help to define the number and duration of tag deployments necessary to produce statistically reliable results.
Spatial Scale	• Species- and project-specific; each tagged animal will actually define its own spatial scale. • Given the likelihood of an individual tagged animal moving far beyond the boundaries of any given project study area; a large-scale tagging/telemetry study may be one of the better methods for addressing cumulative impacts of multiple MRE projects along broad areas of the U.S. coastline.
Other Considerations **(E.g. Advantages or Disadvantages)**	Tagging is logistically challenging, entails high costs, and poses some risk to the animals; in addition it can be difficult to generate effective sample sizes, with the expectation that some proportion of tagged individuals will leave the study area.
Relationship to other protocols	Tagging is similar to the stress hormone protocol (Protocol 6) in that it gets more into effects research that might be conducted if other monitoring results suggest that there might be effects.
Cost (High, Medium, Low)	Medium to High (Annually)
Data Format	The type of data resulting from tagging studies can be extremely variable, and will be dependent upon the type of tags employed.
Data Output	All tagging will result in some level of geospatial data—locations of the tagged individual at particular times. Depending on the tag, these can range from simply deployment and recovery locations for flipper tags to small numbers of locations per day for satellite or geo-locator tags, to detailed movement tracks for GPS archival tags. Telemetry tags with depth sensors to monitor diving

	behavior can provide simple data summaries (e.g., number of dives in the previous 24 hours, maximum depth) for tags with restricted reporting bandwidth to detailed, continuous dive profiles for days to months in the case of archival tags. Methods have been developed for taking the depth and accelerometer data from DTAGs and deriving 3-dimensional graphics or even animations of the submerged foraging behavior of tagged whales (Ware et al., 2006).
Examples where this methodology has been used	Tougard et al., 2003; Teilmann et al., 2006b; Müller and Adelung, 2008; Friedlander et al. 2009; Miller et al. 2009; Nowacek et al, 2004 (See also Appendix E)

Marine Mammals & Sea Turtles Protocol Z6: Underwater Photography

MONITORING OBJECTIVE: Disturbance or loss of habitat of sea turtles by device removal during decommissioning.

Indicator(s) of the impact	Disturbance of animals during cable or device removal; detection of dead or injured animals
Methodology or Technique to Collect Data	Underwater photography via mounted camera of sea turtles and marine mammals to evaluate habitat use
Description of Methodology or Technique(s) to Collect Data	• Underwater camera mounted on ORED structure(s) to collect time-lapse photography of "resident" sea turtles and marine mammals prior to structure(s) decommissioning. • Could be combined with fisheries ROV/SCUBA survey efforts. (See Appendix E for more details)
Methodology for Analyzing data	Direct reporting of data; qualitative analysis to detect presence/absence of marine mammals or turtles
Frequency and Duration	Begin monitoring 1 month prior to cable-laying/removal or decommissioning of structure(s), on day of laying/removal, and 1 month following removal; avoid nighttime removals.
Spatial Scale	Small: Area immediately surrounding structure to be removed
Other Considerations **(E.g. Advantages or Disadvantages)**	Time-lapse underwater photography is preferred method, since it is unobtrusive and provides more complete coverage.
Relationship to other protocols	Can be combined with Fisheries Protocol X3 Could be combined with fisheries ROV/SCUBA survey efforts (Z8 and Z9)
Cost (High, Medium, Low)	Low
Data Format	Individual sightings records, including species identification, size estimates (if possible), and behavioral characteristics noted.
Data Output	Video record and direct reporting of individual "resident" marine mammals and turtles in vicinity of ORED structures would trigger mitigation actions to disperse/relocate/fire warning charges to prevent impacts.
Examples where this methodology has been used	Rosman et al., 1987; Klima et al., 1988

Marine Mammals & Sea Turtles Protocol Z7: SCUBA Surveys

MONITORING OBJECTIVE: Disturbance of sea turtles during cable installation or removal; Disturbance or loss of habitat of sea turtles by device removal during decommissioning.

Indicator(s) of the impact	Disturbance of sea turtles during cable installation/removal; Disturbance of animals during cable or device removal; detection of dead or injured animals
Methodology or Technique to Collect Data	Underwater surveys of sea turtles and marine mammals to evaluate habitat use
Description of Methodology or Technique(s) to Collect Data	• SCUBA diver surveys (e.g. during cable laying/removal or around structures to be decommissioned/removed). • Could be combined with fisheries ROV survey efforts.
Methodology for Analyzing data	Direct reporting of data; qualitative analysis to detect presence/absence of marine mammals or turtles
Frequency and Duration	Begin monitoring 1 month prior to cable-laying/removal or decommissioning of structure(s), on day of laying/removal, and 1 month following removal; avoid nighttime removals.
Spatial Scale	Small: Area immediately surrounding structure to be removed
Other Considerations **(E.g. Advantages or Disadvantages)**	Diver surveys are useful, but can miss turtles, likely due to submersible/observer presence
Relationship to other protocols	Can be combined with Marine Mammal and Sea Turtle Protocol Z7 and Z9; Fisheries Protocol X3
Cost (High, Medium, Low)	Medium
Data Format	Individual sighting records, including species identification, size estimates (if possible), and behavioral characteristics noted.
Data Output	Direct reporting of individual marine mammals and turtles in vicinity of cable-laying or resident animals at ORED structures would trigger mitigation actions to disperse/relocate/fire warning charges to prevent impacts.
Examples where this methodology has been used	Klima et al., 1988; Rosman et al. 1987

Marine Mammals & Sea Turtles Protocol Z8: ROV Surveys

MONITORING OBJECTIVE: Disturbance of sea turtles during cable installation or removal; Disturbance or loss of habitat of sea turtles by device removal during decommissioning.

Indicator(s) of the impact	Disturbance of sea turtles during cable installation/removal; Disturbance of animals during cable or device removal; detection of dead or injured animals
Methodology or Technique to Collect Data	Underwater surveys of sea turtles and marine mammals to evaluate habitat use
Description of Methodology or Technique(s) to Collect Data	• Video surveys with ROV (e.g., during cable laying/removal or around structures to be decommissioned/removed). • Survey areas directly surrounding structures to be removed or along the path where cable-laying/removal will occur.
Methodology for Analyzing data	Direct reporting of data; qualitative analysis to detect presence/absence of marine mammals or turtles
Frequency and Duration	• Begin monitoring 1 month prior to cable-laying/removal or decommissioning of structure(s), on day of laying/removal, and 1 month following removal; avoid nighttime removals. • Could be combined with fisheries ROV survey efforts.
Spatial Scale	Small: Area immediately surrounding structure to be removed or ahead of jet plow along path of cable laying/removal
Other Considerations **(E.g. Advantages or Disadvantages)**	ROV surveys can miss animals, likely due to submersible/observer presence or underwater visibility considerations, but are not weather-/sea state-dependent.
Relationship to other protocols:	Can be combined with Marine Mammal and Sea Turtle Protocol Z7 and Z8; Fisheries Protocol X3
Cost (High, Medium, Low)	Low if combined with fisheries surveys; medium if conducted independently
Data Format	Individual sightings records, including species identification, size estimates (if possible), and behavioral characteristics noted.
Data Output	Direct reporting of individual marine mammals and turtles in vicinity of cable-laying or resident animals at MRE structures would trigger mitigation actions to disperse/relocate/fire warning charges to prevent impacts.
Examples where this methodology has been used	Rosman et al. 1987

9. MULTIPLE PROJECTS/CUMULATIVE IMPACTS

We also considered circumstances in which there are several ORE devices in a region (Scale 3; see the Task 1.2 Report). We determined that it would be infeasible to develop monitoring protocols that address multiple projects or cumulative impacts at this point in time and within the context of this project. While the likelihood of an effect at the stock or population scale may increase with multiple ORE projects in a given area, not enough conclusive evidence exists at this point to indicate whether those effects are compounded, or increase in a nonlinear fashion. At the stage in which there are multiple projects in an area, monitoring may need to occur on a regional scale to understand the magnitude of effect and/or over a longer time series, and data collected from separate projects may need to be analyzed together to more completely understand what is happening. Meta-type analyses could be considered to attempt to get the most out of the data collected from multiple projects.

At the same time, as monitoring data are collected at single projects and analyzed, the potential effects at the individual project level will become better understood, and some of these potential effects may be eliminated from a cumulative impact study as they are found to be negligible. However, in some cases an effect could be negligible when there is a single project, but more important when combined from multiple projects. It is not known *a priori* which situation is applicable to a particular project-species interaction. The report developed for Objective 2 addresses this question to an extent (see Task 2.3 Report), which describes a conceptual framework and approach for evaluating the cumulative impacts of offshore renewable energy development on ecological and socio-economic resources on a larger scale.

10. TESTING THE MONITORING PROTOCOL FRAMEWORK WITHIN THE OCEAN SAMP

In order to test our monitoring protocol framework in the Rhode Island Ocean SAMP area, we developed two test cases. These test cases evaluate whether the framework would be appropriate for selecting monitoring protocols in a real-life situation. The two test cases presented here are the Block Island Wind Farm (BIWF) and the Massachusetts and Rhode Island Wind Energy Area (WEA), both areas slated for development and located within the Rhode Island Ocean SAMP study area.

10.1 BLOCK ISLAND WIND FARM TEST CASE

10.1.1 Overview

The BIWF is a demonstration-scale wind farm projected to be built in state waters within three nautical miles (5.6 km) of the southern coast of the island of Block Island, Rhode Island (Figure 2). As of the writing of this report, construction is expected in 2014. Block Island itself is about 16 km from the coast of Rhode Island. BIWF will have five wind turbines of 6 MW each installed on lattice-jacket structures. This construction process will require pile driving for the foundations; undersea cabling will be installed between turbines and connecting the wind farm to Block Island and Block Island to mainland Rhode Island (see Figure 2).

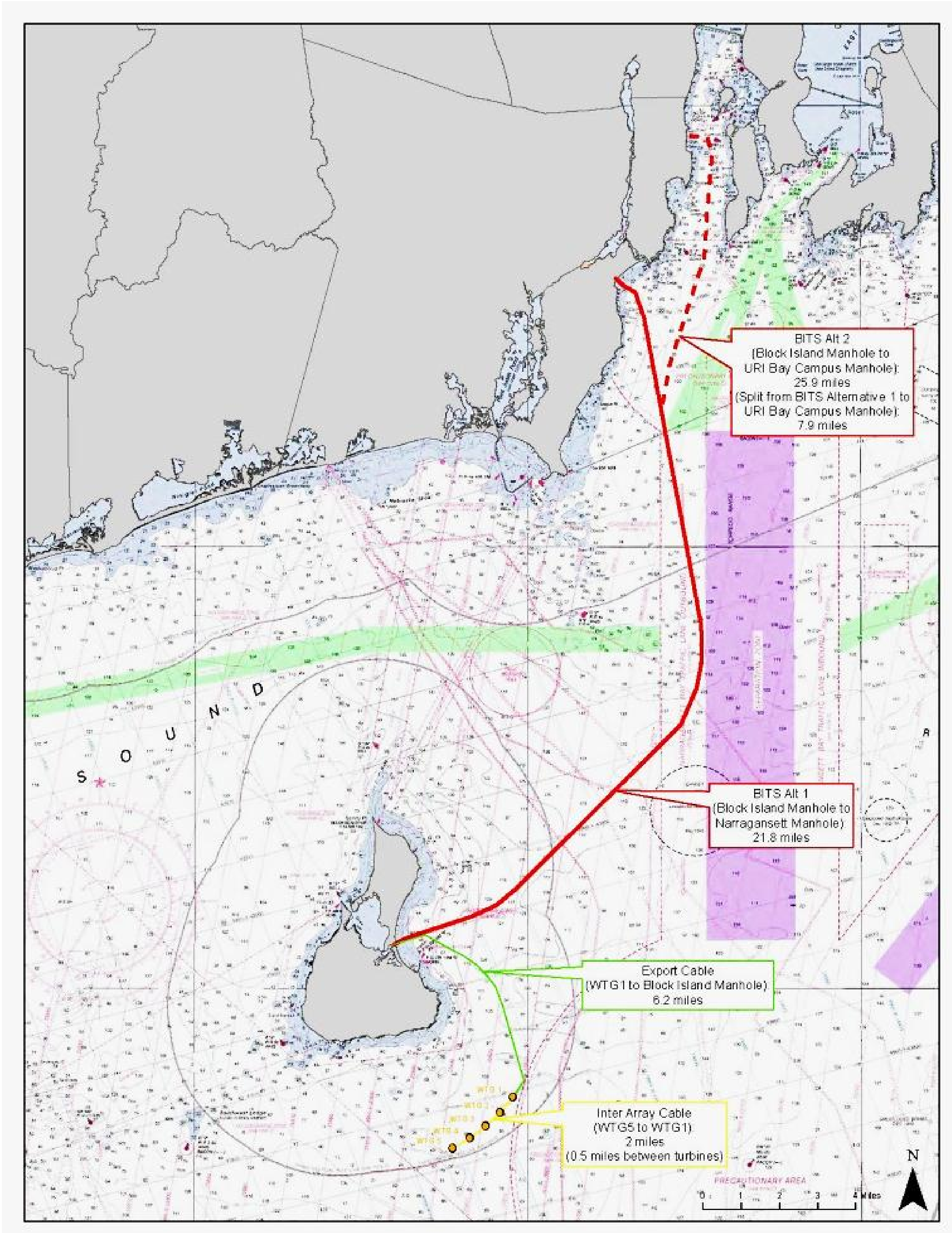


Figure 2. Block Island, Rhode Island — projected locations of wind farm and cables.

10.2 POTENTIAL EFFECTS

Overall the potential effects resulting from a demonstration-scale project are expected to be minor. However, because of the level of uncertainty around any ORE project, and because a larger-scale wind farm is likely to be constructed elsewhere off the Rhode Island coast, the monitoring requirements should make use of this opportunity to study some of the potential impacts of ORE projects before a commercial-scale facility is put into place. Based on the results of the Decision Tree for a demonstration-scale facility, shown in Appendix A, we identified those effects thought to be minor but with high levels of certainty, and recommend that those should be monitored (Table 2). Those potential effects with higher certainty are likely to be easier to study and to generate useful results because there is already a large body of research associated with these effects. The results of monitoring these effects can be used to scale up and apply successful monitoring protocols to larger projects. The potential impacts thought to be major at the commercial wind farm scale are indicated in bold letters. Appendix A also provides examples of each of the decision trees followed to the protocols on the end based on the Block Island wind farm as a test case, with the appropriate technology and environmental types highlighted for this particular example.

Table 2

Potential effects of demonstration-scale wind projects with high certainty.

All potential effects are predicted to be minor at this scale; those in bold are predicted to be major at a commercial-scale facility and those in italics are predicated to be moderate.

Component (not ranked)	Effect
Benthic Habitat and Resources	• *Disturbance from installation/removal of device (including turbidity)* • *Disturbance from installation or removal of power cable (including trenching)* • **Scour around structures** • Smothering by excavated sediments • Reef effects • Diffusion/flaking of marine coating • *Chemicals discharged during installation or removal* • *Resuspension of pollutants in sediments*
Fish Species and Fishing Activity	• Disturbance from installation or removal of device • Disturbance from installation or removal or power cable • Reef effects • **Loss of access to grounds during construction** • **Loss of access to grounds during operation**
Avian Species	• **Displacement or attraction to structure above surface of the water (wind turbines)** • *Displacement or attraction to structure below the surface of the water* • Disturbance from installation of device or transmission cable • *Collision with rotating turbine blades*

Marine Mammals and Sea Turtles	• *Strike by installation or support vessel* • Leakage or discharge of chemicals; spills or accidents • Resuspension of pollutants in sediments • *Operational noise – wind turbines* • **Noise from pile driving** • Noise from directional drilling for power cable • Noise from vessel traffic • *Noise from pile cutting during device removal*

10.2.1. Recommendations

Monitoring priorities should be selected based on site-specific conditions, and will be chosen at the discretion of the regulators. At the BIWF project site, bird species of concern include scoters and red-throated loons, both of which are cryptic and easily disturbed. These species are also present at the RI/MA WEA. Monitoring protocols addressing these species would be appropriate to implement in order to better understand the impacts in bold above. Both demersal fishes and lobster are target species for monitoring because of their importance to commercial fishing in the both the BIWF area and the WEA, so both trawl surveys and ventless trap surveys would be used. Using the Decision Trees and knowledge of species important at this site, we created a list of appropriate monitoring protocols to choose from when assembling a monitoring plan (Table 3).

As discussed in Section 4 there are many potential effects for which considerable uncertainty exists, and when possible these effects should be studied through field-based experiments in order to reduce this uncertainty. The potential effect of EMF is one such example; the effect that EMF may have on crustaceans such as lobster is largely unknown, but could be ecologically meaningful (Normandeau Associates Inc. et al., 2011). Because lobster are an important commercial species in Rhode Island waters, regulators might consider including EMF effect monitoring in any monitoring plans for these developments.

Although not final, the monitoring protocols selected for BIWF are based largely upon a combination the effects that may be of greater concern for a larger-scale project and the species known to be of importance to the local area. We recognize that it infeasible to conduct all of these studies, particularly for a demonstration-scale project; it would be up to the relevant regulators and developers to select from among these.

Table 3

Applicable monitoring protocols to choose from for the Block Island Wind Farm test case.

Monitoring Protocols for Benthic Habitat and Resources
W1. Scour and/or deposition
W2. Changes in benthic community composition
W3. Increase in hard bottom habitat
Monitoring Protocols for Fish and Fishing Activity

X1a. Trawl surveys
X2b. Ventless trap surveys
X5. Spatial use of fishing activity
Monitoring Protocols for Avian Species
Y3. Aerial surveys using high definition videography
Y4. Aerial surveys using digital still photography
Y5. Radar surveys
Y6. Visual surveys of flight ecology
Y11. Remote detection system
Monitoring Protocols for Marine Mammals and Sea Turtles
Z1. Visual surveys
Z2. Passive acoustic monitoring
Z3. Marine mammal observers
Z4. Stranding response networks

10.3. Rhode Island and Massachusetts WEA Commercial-Scale Wind Farm Test Case

10.3.1. Overview

The second test case, for a commercial-scale project, was conducted using a hypothetical wind farm in the WEA defined by BOEM in federal waters off the Massachusetts and Rhode Island coasts (Figure 3). A wind farm being planned for this area may include around 200 turbines with jacketed structures. Because this wind farm would be in the same region as the BIWF, the ecological concerns are largely the same. However, this would be a commercial-scale wind facility, and additional monitoring requirements would apply.

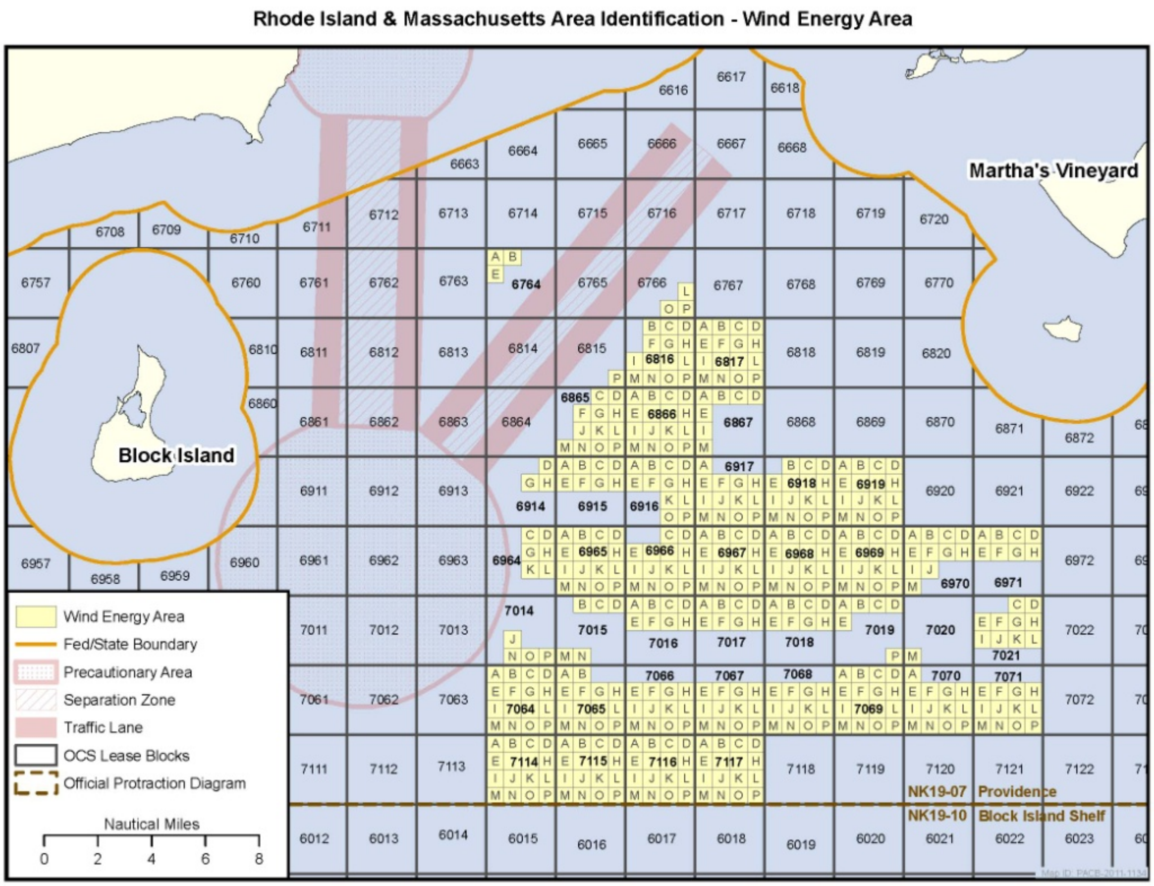


Figure 3. Sites available for ORE development (yellow shading) in federal waters offshore of Rhode Island and Massachusetts.

10.3.2. Potential Effects

Because the technology type and the ecological concerns for this case study are the same as for the Block Island example (Appendix B), the resulting monitoring protocols selected by the Decision Trees are the same. However, the Effects Scenarios differ (see Appendix B). The Decision Trees were used to identify the components that should be monitored with anticipated major and moderate effects (Table 4). Monitoring for potential major effects should be required, whereas monitoring for potential moderate effects should be recommended. There are four potential major effects (Loss of access to grounds during construction and operation for commercial mobile-gear fishermen; displacement or attraction to a device for avian species; sediment scour and/or deposition; and noise from pile driving for marine mammals), and an additional 24 moderate potential effects. Many of these potential effects can be combined for monitoring under the listed protocols.

Table 4

Major and moderate potential effects for commercial-scale wind turbine projects involving pile driving.

Component	Major Effects	Certainty
Fish Species and Fishing Activity	• Loss of access to grounds during construction and operation (mobile gear)	• HIGH
Avian Species	• Displacement or attraction to structure above water surface	• HIGH
Benthic Habitat and Resources	• Scour and/or deposition	• HIGH
Marine Mammals and Sea Turtles	• Noise from pile driving	• MEDIUM

Component	Moderate Effects	Certainty
Benthic Habitat and Resources	• Resuspension of pollutants in sediments • Chemical spills, discharge • Disturbance from installation of cable • Changes to current/wave regime	• HIGH • MEDIUM • MEDIUM • MEDIUM
Fish Species and Fishing Activity	• Chemical spills • Operational noise • Noise from pre-construction seismic surveys • Noise from pile driving • Noise from pile cutting during device removal • EMF • Habitat/community composition alteration • Decreased catchability during construction and operation • Loss of access to grounds during construction and operation (fixed gear and recreational) • Changes in species distribution • Damaged/lost gear	• MEDIUM • MEDIUM • MEDIUM • MEDIUM • MEDIUM • LOW • MEDIUM • MEDIUM • HIGH • LOW • HIGH
Avian Species	• Displacement or attraction to structure below water surface • Collision with rotating turbine blades • Pressure gradients around rotor • Leakage of lubricants/fluids; release of maintenance chemicals • Large chemical spills	• MEDIUM • HIGH • MEDIUM • MEDIUM • HIGH
Marine Mammals and Sea Turtles	• Entanglement with mooring lines or cables • Strikes with installation or support vessels • Operational noise • Noise from pile cutting during device removal	• MEDIUM • HIGH • MEDIUM • HIGH

10.3.3. Recommendations

There are 24 monitoring protocols applicable to the RI/MA WEA commercial-scale wind farm test case (Table 5). Because details for the WEA development are unknown, the applicable monitoring protocols are hypothetical. When regulators are ready to consider monitoring activities for this project, we recommend they confirm the accuracy of the decision tree information, consider what was learned from the demonstration-scale project, and then develop the monitoring program.

Table 5

Applicable monitoring protocols to choose from for the RI/MA WEA test case.

Monitoring Protocols for Benthic Habitat and Resources
W1. Scour and/or deposition
W2. Changes in benthic community composition
W3. Increase in hard bottom habitat
Monitoring protocols for Fish and Fishing Activity
X1a. Trawl surveys
X1b. Ventless trap surveys
X2. Habitat alteration/community composition
X3. Reef effects
X4. Spatial use of fishing activity
Monitoring Protocols for Avian Species
Y3. Aerial surveys using high definition videography
Y4. Aerial surveys using digital still photography
Y5. Radar surveys
Y6. Visual surveys of flight ecology
Y11. Remote detection system
Monitoring Protocols for Marine Mammals and Sea Turtles
Z1. Visual surveys
Z2. Passive acoustic monitoring
Z3. Marine mammal observers
Z4. Stranding response networks
Z5. Tagging
Z8. ROV surveys

10.4. USING THE MONITORING PROTOCOL FRAMEWORK TO INFORM FUTURE SITING

The data collected through the monitoring protocols described in Section 9 can also be used to inform better siting for future projects. As part of creating the Ocean SAMP, two indices were developed to provide a systematic approach to project siting as a means of evaluating the relative potential impacts of a proposed project based on its location. The first index, the Technology Development Index (TDI) is a quantitative indicator of the development "value" of a given location based on the technical challenge of development and the power production potential at a given site. The second index, the Ecological Value Index (EVI), is a quantitative and integrative metric of ecological value at a given site (French-McCay et al., 2011). Baseline and monitoring data collected in a standardized way through the protocols described in Section 9 will allow the data to be compiled more easily and used to inform both the TDI and the EVI, making these tools more robust and useful in evaluating future projects.

10.4.1. Technology Development Index

The TDI, developed by Spaulding et al. (2010), is defined as the ratio of the Technical Challenge Index (TCI) to the Power Production Potential (PPP). TCI is a measure of how difficult it is to construct a facility (e.g., an offshore wind project) at a given location plus a measure of the distance to the closest electrical grid connection point. This measurement can be expressed as the cost in dollars of installation, or if cost data are unavailable, as a relative estimate ranked by the level of difficulty based on professional judgment (i.e. 1 to 5, with 5 being the most difficult). PPP is an estimate of the annual power production possible at the location measured in watts, determined from wind resource measurement. Sites with the lowest TDI value represent the optimum sites for development.

$$\text{Technology Development Index (TDI)} = \frac{\text{Technical Challenge Index (TCI)}}{\text{Power Production Potential (PPP)}}$$

Tools such as the TDI can be applied to the site-selection process conducted for any type of development project. Spaulding et al. (2010b, 2010c) applied the TDI analysis to offshore wind energy development, though this process may help to inform the siting of any ORE project.

Acquisition of additional data from implementing the monitoring protocols discussed in Section 9 would not result in any changes being made to the TDI framework. The protocols provide site-specific ecological data rather than broad scale physical environmental data, and would not be useful in a site-selection tool such as the TDI.

10.4.2. Ecological Value Index and Cumulative Use Evaluation Model

The EVI framework serves as a tool to help identify areas that have greater ecological value and therefore may be less suitable for an ORE or other development. Ecological value was defined as the intrinsic value of biodiversity without reference to anthropogenic use.

French-McCay et al. (2011) modeled the ecological value of the Ocean SAMP area by inputting geospatial data collected by Ocean SAMP researchers that described fish and wildlife species distributions (i.e., as actual measures of biodiversity) or proxies of biodiversity (e.g., geophysical environment variables).

To assess which areas may be most affected by construction or operation of an ORE facility, the NOPP research team built upon the Ocean SAMP EVI framework to develop a Siting Evaluation Model (SEM), which is comprised of several indices, including the TDI and Cumulative Use Evaluation Model (CUEM) (see the Task 2.3 Report). The CUEM is composed of indices representing both ecological and human use, the Cumulative Impact Model-Ecological (CIM-Eco) and the Cumulative Impact Model-Human Use (CIM-HU). The CIM-Eco portion of the CUEM allows the user to input a relative impact level associated with a particular ORE activity to view which areas may be most affected based on the underlying ecological resources. The results of the CIM-Eco calculator may be combined with the results of CIM-HU to evaluate the impacts of a development. With the CUEM and TDI, the topology of the full SEM (including uncertainties) would identify areas most suitable for ORE development.

The framework that we developed for this project informs the use of these models and improves their performance in a number of ways. First, having standardized methods for collecting baseline and impact data across projects will allow the data to be compiled more easily and incorporated into tools such as the SEM. Standardized data would improve our confidence in model results, and this was one of the primary conclusions of the Task 2.3 Report. Furthermore, the CIM-Eco calculator requires the user to weight ecological components based on effects they experience from a particular development type. Our examination of effects and description of Effects Scenarios contribute quantitative information towards an informed effects weighting scheme (see Task 2.3 Report). Lastly, data that are collected using our monitoring protocols can feed back into this effects assessment and inform weighting schemes in the CIM-Eco calculator. For example, if monitoring studies conducted at demonstration-scale projects suggest that EMF effects are negligible, the CIM-Eco score can be adjusted to reduce the weighting of EMF effects in the analysis.

11. CONCLUSIONS AND RECOMMENDATIONS

This report presents protocols for monitoring the environmental impacts of ORE, along with a framework for selecting appropriate protocols for a given project. We created monitoring protocols that are based on the best available science, along with existing technology and technology currently in development. These protocols represent a first step in standardizing data collection to better understand the potential impacts of ORE projects on the environment. While we have designed the protocols and decision trees to be adaptive to accommodate new knowledge or changes in technology, we also recognize that these may need to be updated as new information becomes available.

Currently there is a great deal of uncertainty surrounding the environmental effects of ORE technologies. Through implementing a comprehensive monitoring program at each new ORE project, and by comparing and aggregating data, much of this uncertainty will be reduced and potential adverse effects will be better understood. Where potential adverse effects are poorly understood, separating an observed effect from the driver of the effect can be especially difficult. In some situations, initial effects may result in secondary or cascading effects that may not be observable for several years after installation. In these cases, additional scientific research, including both laboratory and field experiments, is necessary and warranted.

The Offshore Renewable Energy Effect Matrix developed as part of Task 1.2 analyzed what the level of certainty is within the literature for a variety of potential effects. Those effects found to have low levels of certainty are those for which additional research should be conducted. We recommend research funding and effort be directed toward understanding the level of risk of the following potential effects:

Benthic Habitat and Resources:

- Changes to currents or wave regimes
- Increase in sediment temperature around cable
- Reef effects on MHK devices
- Noise effects from construction, operation, and decommissioning
- EMF effects from the power cables

Fisheries Resources and Fishing Activity:

- Effect of pressure and velocity gradients around a rotor, and rotor wake, for tidal devices
- Potential for chemical discharge, including leaking, spills, or flaking of marine coating
- Noise effects, including pre-construction noise from seismic surveying, construction noise, vessel noise, and operational noise
- EMF effects from the power cables
- Changes to community composition from reef effects or disturbance

- Changes in species distribution

Avian Species:

- Collision with rotating turbine blades from tidal devices
- Pressure and velocity gradients around a rotor for both tidal and wind turbines
- EMF effects from the power cables
- Changes to foraging due to changes in turbulent dissipation/boundary layers for MHK devices
- Changes to foraging due to changes in the wave energy regime, for all device types

Marine Mammals and Sea Turtles:

- Reef effects from devices
- Entanglement with mooring lines or cables
- Potential for effects from diffusion or flaking of marine coating
- Effects of operational noise, especially from tidal and wave energy devices
- EMF effects from the power cables

The potential for impacts from electromagnetic fields (EMF) on all species has emerged as a particular issue of concern; there is considerable uncertainty around what the impacts of EMF might be on each of the ecosystem components considered in this report. When possible, we recommend site-based EMF studies be conducted alongside other monitoring projects.

Monitoring programs need to be adaptive to both regulatory needs and local concerns. In drafting a set of protocols we attempted to account for variability in regions, target species, etc., but decisions about the most appropriate ways to monitor an ORE projects will still have to be made on a case-by-case basis. This report provides guidance in selecting the appropriate protocols and in standardizing protocols across projects, but as the Block Island case study demonstrates, the final decision about what is most needed and appropriate, particularly at the demonstration-scale, will be made by regulators based on what they know to be local concerns.

The data collected through a standardized monitoring program will provide a means for refining our understanding of the potential effects of ORE projects, and will allow for better siting decisions. It is our hope that the results will prove useful to regulators in navigating the questions of what to monitor and how, facilitating the permitting process.

LIST OF REFERENCES

Other Project M10PC00097 Reports Cited

Task 1.2 Report — *Monitoring the Potential Effects of Offshore Renewable Energy:* http://www.seagrant.gso.uri.edu/coast/internal/nopp/1.2_Report.pdf

Task 1.3 Report — *A Comprehensive Review and Critique: Existing U.S and International Monitoring Protocols for Offshore Renewable Energy Development and Other Marine Construction:* http://www.seagrant.gso.uri.edu/coast/internal/nopp/1.3_Report.pdf

Task 1.4 Report — *Standardized Protocols for Assessing the Effects of Offshore Alternative Energy Development on Cultural Resources:* http://www.seagrant.gso.uri.edu/coast/internal/nopp/4.0_Report.pdf

Task 2.3 Report — *Framework for Cumulative Impact Evaluation:* http://www.seagrant.gso.uri.edu/coast/internal/nopp/2.3_Report.pdf

Literature Cited — includes citations in Appendices

Allee, R., G. Cicchetti, M. Finkbeiner, K. Goodin, L. Handley, C. Madden, G. Mayer, E. Shumchenia, and J. Soule (eds.) 2012. Coastal and Marine Ecological Classification Standard. Report FGDC-STD-018-2012. Marine and Coastal Spatial Data Subcommittee, Federal Geographic Data Committee, Reston, VA. 343 pp. Available online: http://www.csc.noaa.gov/digitalcoast/publications/cmecs

Allen, B.M., and R.P. Angliss. 2011. Alaska Marine Mammal Stock Assessments, 2010. NOAA Technical Memorandum NMFS-AFSC-223. National Marine Fisheries Service, Seattle, WA.

Anonymous. 2010. History of the Northeast Region Stranding and Disentanglement Network. National Marine Fisheries Center, Northeast Regional Office, Gloucester, MA. http://www.nero.noaa.gov/prot_res/stranding/NERStrandingHistory.pdf

Barlow, J., M.C. Ferguson, E.A. Becker, J.V. Redfern, K.A. Forney, I.L. Vilchis, P.C. Fiedler, T. Gerrodette, and L.T. Balance. 2009. Predictive Modeling of Cetacean Densities in the Eastern Pacific Ocean. NOAA Tech Memo NMFS-SWFSC-444. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA.

Becker E.A., K.A. Forney, M.C. Ferguson, D.G. Foley, R.C. Smith, J. Barlow, and J.V. Redfern. 2010. Comparing California Current cetacean-habitat models developed using in situ and remotely sensed sea surface temperature data. Marine Ecology Progress Series 413:163–183.

Bogomolni, A.L., K.R. Pugliares, S.M. Sharp, K. Patchett, C.T. Harry, J.M. LaRocque, K.M. Touhey, and M. Moore. 2010. Mortality trends of stranded marine mammals on Cape Cod and southeastern Massachusetts, USA, 2000 to 2006. Diseases of Aquatic Organisms 88:143-155.

Boehlert, G.W. and A.B. Gill. 2010. Environmental and ecological effects of ocean renewable energy development: A current synthesis. Oceanography 23:68-81.

Bonzek, C.F. J. Gartland, R.A. Johnson, and J.D. Lange Jr. 2008. NEAMAP Near Shore Trawl Survey: Peer Review Documentation. A report to the Atlantic States Marine Fisheries Commission, Arlington, VA. http://www.neamap.net/publications/VIMS_NEAMAP_Peer_Review_Documents.pdf

Buckland, S.T., L.M. Burt, E.A. Rexstad, M. Mellor, A.E. Williams, and R. Woodward. In press. Aerial surveys of seabirds: the advent of digital methods. Journal of Animal Ecology.

Camphuysen, K.C.J., A.D. Fox, M.F. Leopold, and I.K. Petersen. 2004. Towards Standardized Seabirds at Sea Census Techniques in Connection with Environmental Impact Assessments for Offshore Wind Farms in the U.K. A Comparison of Ship and Aerial Sampling Methods for Marine Birds, and Their Applicability to Offshore Wind Farm Assessments. Commissioned by COWRIE Ltd. Royal Netherlands Institute for Sea Research, Altera, Netherlands.

Carey, J.M., and M.J. Keough. 2002. The variability of estimates of variance, and its effect on power analysis in monitoring design. Environmental Monitoring and Assessment 74, 225–41.

Carretta, J.V., K.A. Forney, E. Oleson, K. Martien, M.M. Muto, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, D. Lynch, L. Carswell, R.L. Brownell Jr., J. Robbins, D.K. Mattila, K. Ralls, and M.C. Hill. 2011. U.S. Pacific Marine Mammal Stock Assessments: 2010. NOAA Technical Memorandum NMFS-SWFSC-476. National Marine Fisheries Service, La Jolla, CA.

CEFAS (Centre for Environment, Fisheries & Aquaculture Science). 2004. Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements. CEFAS, Lowestoft, UK.

CETAP (Cetacean and Turtle Assessment Program, University of Rhode Island). 1982. A Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic Areas of the U. S. Outer Continental Shelf, Final Report. Contract AA551-CT8-48. Bureau of Land Management, Washington, DC.

Courchene, B., and K.D.E. Stokesbury. 2011. Comparison of vented and ventless trap catches of American lobster with Scuba transect surveys. Journal of Shellfish Research 30(2): 389-401.

Degraer, S., R. Brabant, and R. Rumes. 2011. Offshore Wind Farms in the Belgian Part of the North Sea: Selected Findings from the Baseline and Targeted Monitoring. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit, Brussels, Belgium.

Desholm, M., A.D. Fox, and P.D. Beasley. 2004. Best Practice Guidance for the Use of Remote Techniques for Observing Bird Behavior in Relation to Offshore Wind Farms. . Report

REMOTE-05-2004 for COWRIE. Dept. of Wildlife Ecology and Biodiversity, National Environmental Research Institute, Ronde, Denmark.

Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1:296–298.

Desholm, M., A.D. Fox, P.D. Beasley, and J. Kahlert. 2006. Remote techniques for counting and estimating the number of bird-wind turbine collisions at sea: a review. Ibis 148:76-89.

DoN (Department of the Navy). 2009. United States Navy Integrated Comprehensive Monitoring Program. U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, DC.

Edrén, S.M.C., S.M. Andersen, J. Teilmann, J. Carstensen, P.B. Harders, R. Dietz, and L.A. Miller. 2010. The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. Marine Mammal Science 26:614-634.

Ferguson, M.C., J. Barlow, P. Fiedler, S.B. Reilly, and T. Gerrodette. 2006a. Spatial models of delphinid (family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. Ecological Modeling 193:645-662.

Ferguson, M.C., J. Barlow, S.B. Reilly, and T. Gerrodette. 2006b. Predicting Cuvier's (*Ziphius cavirostris*) and *Mesoplodon* beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. Journal of Cetacean Research and Management 7:287–299.

Forney, K.A. 2000. Environmental models of cetacean abundance: reducing uncertainty in population trends. Conservation Biology 14:1271-1286.

Frankel, A.S., and C.W. Clark. 1998. Results of low-frequency M-sequence noise playbacks to humpback whales in Hawai'i. Canadian Journal of Zoology 76:521-535.

Frankel, A.S., and C.W. Clark. 2000. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. Journal of the Acoustical Society of America 108(4):1930-1937.

French McCay, D., M. Schroeder, E. Graham, D. Reich, and J. Rowe. 2011. Ecological Value Map (EVM) for the Rhode Island Special Area Management Plan (report). Rhode Island Coastal Resources Management Council, Wakefield, RI.

Friedlander, A.S., E.L. Hazen, D.P. Nowacek, P.N. Halpin, C. Ware, M.T. Weinrich, T. Hurst, and D. Wiley. 2009. Diel changes in humpback whale *Megaptera novaeangliae* feeding behavior in response to sand lance *Ammodytes* spp. behavior and distribution. Marine Ecology Progress Series 395:91-100.

Griffin, L., E. Rees, and B. Hughes. 2010. The Migration of Whooper Swans in elation to Offshore Wind Farms. Report to COWRIE Ltd. Wildfowl & Wetlands Trust, Slimbridge, UK.

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104–115. http://dx.doi.org/10.5670/oceanog.2009.42.

Hogg, C.J., T.L. Rogers, A. Shorter, K. Barton, P.J.O. Miller, and D. Nowacek. 2009. Determination of steroid hormones in whale blow: It is possible. Marine Mammal Science 25(3): 605-618.

Inger, R., M.J. Attrill, S. Bearhop, A.C. Broderick, W.J. Grecian, D.J. Hodgson, C. Mills, E. Sheehan, S.C. Votier, M.J. Witt, and B.J. Godley. 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. Journal of Applied Ecology 46:1145-1153.

Kenney, R.D. 2001. The North Atlantic Right Whale Consortium databases. Maritimes 43(2): 3-5.

Kenney, R.D. and C.R. Shoop. 2012. Aerial surveys for marine turtles. Pp. 264-271 in: R.W. McDiarmid, M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff, eds. Reptile Biodiversity: Standard Methods for Inventory and Monitoring. University of California Press, Berkeley, CA.

Kenney, R.D., and K.J. Vigness-Raposa. 2010. Marine Mammals and Sea Turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and Nearby Waters: An Analysis of Existing Data for the Rhode Island Ocean Special Area Management Plan. Final Technical Report to the Rhode Island Office of Energy Resources and Rhode Island Coastal Resources Management Council. University of Rhode Island, Graduate School of Oceanography, Narragansett, RI.

Klima, E.F., G.R. Gitschlag, and M.L. Renaud. 1988. Impacts of the explosive removal of offshore petroleum platforms on sea turtles and dolphins. Marine Fisheries Review 50(3):33-42.

Krijgsveld, K.L., R.C. Fijn, C. Heunks, P.W. van Horssen, J. de Fouw, M. Collier, M.J.M. Poot, D. Beuker, and S. Dirksen. 2010. Effect Studies Offshore Wind Farm Egmond aan Zee: Progress Report on Fluxes and Behaviour of Flying Birds Covering 2007 and 2008. Bureau Waardenburg no. 09-023 to Nordzeewind, Culemborg, Netherlands.

Lapena, B.P., K.M. Wijnberg, S.J.M.H. Hulscher, and A. Stein. 2010. Environmental impact assessment of offshore wind farms: a simulation-based approach. Journal of Applied Ecology 47:1110-1118.

Lapena, B.P., K.M. Wijnberg, S.J.M.H. Hulscher, and A. Stein. 2011a. Simulation-based impact assessment of offshore wind farms on seabirds. Journal of Sustainability Science and Management 6:107-117.

Lapena, B.P., K.M. Wijnberg, A. Stein, and S.J.M.H. Hulscher. 2011b. Spatial factors affecting statistical power in testing marine fauna displacement. Ecological Applications 21:2756–2769.

Leslie, H.M., and K.L. McLeod. 2007. Confronting the challenges of implementing marine ecosystem-based management. Frontiers in Ecology and the Environment 5, 540–548.

Link, J., 2005. Translating ecosystem indicators into decision criteria. ICES Journal of Marine Science 62, 569–576.

Love, M, J. Hyland, A. Ebeling, T. Herrlinger, A. Brooks, and E. Imamura. 1994. A pilot study of the distribution and abundances of rockfishes in relation to natural environmental factors and an offshore oil and gas production platform off the coast of Southern California. Bulletin of Marine Science 53(2-3):1062-1085.

Maclean, I.M.D., H. Skov, M.M. Rehfisch, and W. Piper. 2006. Use of Aerial Surveys to Detect Bird Displacement by Offshore Wind Farms. BTO Research Report No. 446 to COWRIE. British Trust for Ornithology, Thetford, UK.

Maine Department of Marine Fisheries. 2006. Maine Ventless Lobster Monitoring Survey. Available from http://www.maine.gov/dmr/rm/lobster/ventless/overview.pdf .

Malme, C. I., P.R. Miles, C.W. Clark, P. Tyack, and J. E.Bird. 1984. Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior/Phase II: January 1984 Migration. BBN Report 5586 to Minerals Management Service. Bolt Beranek & Newman, Cambridge, MA.

Mellor, M., T. Craig, D. Baillie, and P. Woolaghan. 2007. Trial of High Definition Video Survey and Its Applicability to Survey of Offshore Windfarm Sites. Report commissioned by COWRIE. Hidef Aerial Surveying Ltd., Cumbria, UK.

Mellor, M., and M. Maher. 2008. Full Scale Trial of High Definition Video Survey for Offshore Windfarm Sites. Report commissioned by COWRIE. Hidef Aerial Surveying Ltd., Cumbria, UK.

Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero, and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. Deep-Sea Research I 56(7):1168-1181.

MMS (Minerals Management Service). 2007. Final Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use Facilities on the Outer Continental Shelf. October 2007. Available online at: http://ocsenergy.anl.gov/documents/fpeis/index.cfm.

MMS (Minerals Management Service). 2009. Cape Wind Energy Project; Final Environmental Impact Statement. MMS EIS-EA, OCS Publication No. 2008-40, U.S. Dept. of the Interior, Minerals Management Service, Herndon, VA.

Moore, M.J., W.A. McLellan, P.-Y. Daoust, R.K. Bonde, and A.R. Knowlton. 2007. Right whale mortality: A message from the dead to the living. Pp. 358–379 in: S. D. Kraus and R. M. Rolland, eds. The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press, Cambridge, MA.

Müller, G., and D. Adelung. 2008. Harbor seals, wind farms, and dead reckoning: experiences from the German Wadden Sea. Pp. 37-41 in: P.G.H. Evans (ed.). Proceedings of the ASCOBANS/ECS Workshop; Offshore Wind Farms and Marine Mammals: Impacts and Methodologies for Assessing Impacts. ECS Special Publication Series No. 49, European Cetacean Society, Liege, Belgium.

Muxika, I., A. Borja, and J. Bald. 2007. Using historical data, expert judgment and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. Marine Pollution Bulletin 55, 16–29.

NMFS (National Marine Fisheries Service). 2003. Taking of marine mammals incidental to specified activities; Construction of the east span of the San Francisco-Oakland Bay Bridge; Notice of issuance of an incidental harassment authorization. Federal Register 68(220):54595-64609.

NMFS (National Marine Fisheries Service). 2010a. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to open water marine seismic survey in the Chukchi Sea, Alaska; Notice; issuance of an incidental harassment authorization. Federal Register 75(156):49760-49811.

NMFS (National Marine Fisheries Service). 2010b. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to operation and maintenance of a liquefied natural gas facility off Massachusetts; Notice; issuance of an incidental harassment authorization. Federal Register 75(136):41440-41449.

NMFS (National Marine Fisheries Service). 2010c. Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to operations of a liquefied natural gas port facility in Massachusetts Bay; Notice of issuance of an incidental harassment authorization. Federal Register 75(169):53672-53678.

Normandeau Associates Inc., T. Tricas, and A. Gill. 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

Nowacek, D.P., M P. Johnson, and P.L. Tyack. 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. Proceedings of the Royal Society B Biological Sciences 271:227-231.

NRC (National Research Council). 2000. Marine Mammals and Low-Frequency Sound: Progress Since 1994. National Academy Press, Washington, DC.

OSPAR, 2002. Joint Assessment and Monitoring Programme (JAMP) guidelines on quality assurance for biological monitoring in the OSPAR area. Ref no. 2002-15, 38 pp.

Perrow, M.R., E.R. Skeate, P. Lines, D. Brown, and M.L. Tomlinson. 2006. Radio telemetry as a tool for impact assessment of wind farms: the case of Little Terns *Sterna albifrons* at Scroby Sands, Norfolk, UK. Ibis 148:57-75.

Petersen, I.B., M. MacKenzie, E. Rexstad, M.S. Wisz, and A.D. Fox. 2011. Comparing pre- and post-construction distributions of long-tailed ducks *Clangula hyemalis* in and around the Nysted offshore wind farm, Denmark: a quasi-designed experiment accounting for imperfect detection, local surface features and autocorrelation. CREEM Tech Report 2011-1. Centre for Research into Ecological and Environmental Modelling, St. Andrews, Scotland.

Rademacher, K.R., and J.H. Render. 2003. Fish assemblages around oil and gas platforms in the Northeastern Gulf of Mexico: Developing a survey design. Pp. ??-?? in: D.R. Stanley and A. Scarborough-Bull, eds. Fisheries, Reefs, and Offshore Development. American Fisheries Society Symposium 36. American Fisheries Society, Bethesda, MD.

Redfern, J.V., M.C. Ferguson, E.A. Becker, K.D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M.F. Baumgartner, K.A. Forney, L.T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A.J. Pershing, S.S. Qian, A. Read, S.B. Reilly, L. Torres, and F. Werner. 2006. Techniques for cetacean-habitat modeling: a review. Marine Ecology Progress Series 310:271-295.

Rees, H.L., J.L. Hyland, K. Hylland, C.S.L Mercer Clarke, J.C. Roff, and S. Ware. 2008. Environmental indicators: utility in meeting regulatory needs. An overview. ICES Journal of Marine Science 65, 1381–1386.

Risch, D., P.J. Corkeron, W.T. Ellison, and S.M. Van Parijs. 2011. Changes in humpback whale song occurrence in response to an acoustic source 200 km away. PLoS ONE 7(1):e29741. Doi:10.1371/journal.pone.0029741.

Rolland, R.M., K.E. Hunt, G.J. Doucette, L.G. Rickard, and S.K. Wasser. 2007. The inner whale: hormones, biotoxins and parasites. Pp. 232-272 in: S. D. Kraus and R. M. Rolland (eds.). The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press, Cambridge, MA.

Rolland, R.M., S.E. Parks, K.E. Hunt, M. Castellote, P.J. Corkeron, D.P. Nowacek, S.K. Wasser, and S.D. Kraus. 2012. Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B Biological Sciences doi:10.1098/rspb.2011.2429.

Rosman, I., G.S. Boland, L.R. Martin, and C.R. Chandler. 1987. Underwater sightings of sea turtles in the northern Gulf of Mexico. OCS Study MMS 87-0107. U.S. Dept. of the Interior, Minerals Management Service, New Orleans, LA.

Samhouri, J.F., P.S. Levin, C.A. James, J. Kershner, and G. Williams. 2011. Using existing scientific capacity to set targets for ecosystem-based management: a Puget Sound case study. Marine Policy 35:508-518.

Saunders, G., G.S. Bedford, J.R. Trendall, and I. Sotheran. 2011. Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland. Volume 5. Benthic Habitats. Unpublished draft report to Scottish Natural Heritage and Marine Scotland, Inverness, UK.

Shaffer, S.A., and D.O. Costa. 2006. A database for the study of marine mammal behavior: gap analysis, data standardization, and future directions. IEEE Journal of Oceanic Engineering 31(1):82-86.

Stelzenmüller, V., Breen, P., Stamford, T., Thomsen, F., Badalamenti, F., Borja, Á., Buhl-Mortensen, L., Carlstöm, J., D'Anna, G., Dankers, N., Degraer, S., Dujin, M., Fiorentino, F., Galparsoro, I., Giakoumi, S., Gristina, M., Johnson, K., Jones, P.J.S., Katsanevakis, S., Knittweis, L., Kyriazi, Z., Pipitone, C., Piwowarczyk, J., Rabaut, M., Sørensen, T.K., van Dalfsen, J., Vassilopoulou, V., Vega Fernández, T., Vincx, M., Vöge, S., Weber, A., Wijkmark, N., Jak, R., Qiu, W., ter Hofstede, R., 2012. Monitoring and evaluation of spatially managed areas: A generic framework for implementation of ecosystem based marine management and its application. Marine Policy http://dx.doi.org/10.1016/j.marpol.2012.04.012.

Teilmann, J., J. Tougaard, and J. Carstensen. 2006a. Summary on Harbour Porpoise Monitoring 1999-2006 Around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Teilmann, J., J. Tougaard, J. Carstensen, R. Dietz, and S. Tougaard. 2006b. Summary on Seal Monitoring 1999-2006 Around Nysted and Horns Rev Offshore Wind Farms. Ministry of the Environment, Copenhagen, Denmark.

Thompson, P.M., D. Lusseau, T. Barton, D. Simmons, J. Rusin, and H. Bailey. 2010. Assessing the responses of coastal cetaceans to the construction of offshore wind turbines. Marine Pollution Bulletin 60:1200-1208.

Thomsen, F., S.R. McCully, L.R. Weiss, D.T. Wood, K.J. Warr, J. Barry, and R.J. Law. 2011. Cetacean stock assessments in relation to exploration and production industry activity and other human pressures: review and data needs. Aquatic Mammals 37:1-93.

Tougaard, J., J. Carstensen, and J. Teilmann. 2009. Pile driving zone of responsiveness extends beyond 20 km for harbour porpoises (Phocoena phocoena (L.)). Journal of the Acoustical Society of America 126:11-14.

Vanermen, N., E.W.M. Stienen, T. Onkelinx, W. Courtens, M. Van de Walle, and H. Verstraete. 2010. Monitoring seabird displacement effects by offshore wind farms: a modeling approach. Pp. 133-152 in: S. Degraer, R. Brabant, and B. Rumes, eds. Offshore Wind Farms in the Belgian Part of the North Sea: Early Environmental Impact Assessment and Spatio-temporal Variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit, Brussels, Belgium.

Van den Eynde, D., R. Brabant, M. Fettweis, F. Francken, J. Melotte, M. Sas, and V.V. Lancker. 2010. Monitoring of hydrodynamic and morphological changes at the C-Power and Belwind offshore windfarm sites – A synthesis. Pp. 19-36 in: S. Degraer, R. Brabant, and B. Rumes, eds. Offshore Wind Farms in the Belgian Part of the North Sea: Early Environmental Impact Assessment and Spatio-temporal Variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit, Brussels, Belgium.

Verdant Power. 2010. Roosevelt Island Tidal Energy Project, FERC No. 12611, Final Kinetic Hydropower Pilot Licence Application, Volume 4, Part 1: Proposed Monitoring Plans, RITE Monitoring of Environmental Effects (RMEE). Verdant Energy, LLC, New York, NY. http://www.theriteproject.com/uploads/VPRITE-FLAVol4-Part1of3.pdf

Walls, R.J., C.J. Pendlebury, R. Budgey, K. Brookes, and P. Thompson. 2009. Revised best practice guidance for the use of remote techniques for ornithological monitoring at offshore windfarms. COWRIE Ltd., Thetford, UK.

Ware, C., R. Arsenault, M. Plumlee, and D. Wiley. 2006. Visualizing the underwater behavior of humpback whales. IEEE Computer Graphics and Applications 26(4):14-18.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2010. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2010. NOAA Technical Memorandum NMFS-NE-219. National Marine Fisheries Service, Woods Hole, MA.

Wiley, D.N., J.C. Moller, and K.A. Zilinskas. 2003. The distribution and density of commercial fisheries and baleen whales within the Stellwagen Bank National Marine Sanctuary: July 2001-June 2002. MTS Journal 37(1):35-53.

Wilhelmsson, D., T. Malm, and M. Ohman. 2006. The influence of offshore windpower on demersal fish. ICES Journal of Marine Science 63:775-78.

13. APPENDIX A. BLOCK ISLAND TEST CASE

Appendix A presents the relevant sections of the Effects Decision Tree, Effects Scenario and the Component Decision Trees Effects Scenarios that were used in selecting relevant protocols for the Block Island Wind Farm test case (Section 11).

13.1. Effects Decision Tree for Block Island Test Case

Determine which ecosystem components may experience effects from renewable energy development:

The energy resource is

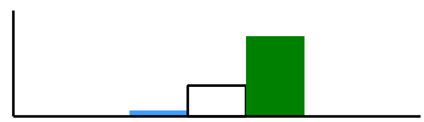
Wind…………………………………………………………………………………………………… Go to A

A. The wind turbine foundation is

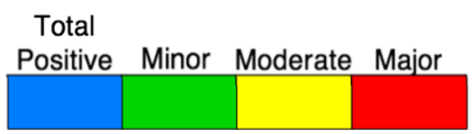
Tripod/Lattice…………………………………………………………………………………… Go to A3

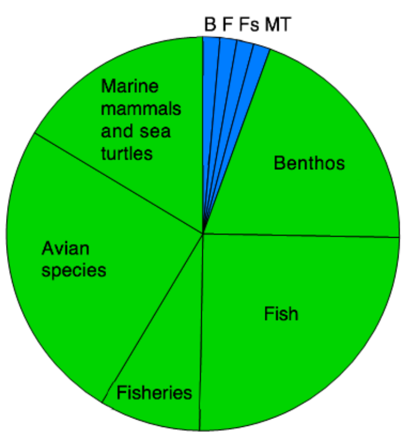
A3. The tripod/lattice wind turbine project scale is

Demonstration…………………………………… Go to E1



Effects Scenario E1—All Demonstration-scale Projects





These projects are listed as “Scale 1” in the Renewable Energy Impact Matrix. The current literature suggests that any renewable energy development, if completed at the demonstration scale, will not have any moderate or major effects on the ecosystem components examined here. Therefore, we list the **potential minor effects** and their certainty in the Effects Decision Tree. Of the suite of minor effects, Benthic Habitat and Resources, Avian Species and Fish Species share an equally high proportion. Across ecosystem components, effects with the highest certainty tend to be physical and chemical disturbances, such as disturbance from device installation, attraction to devices, or chemical spills. Effects with low certainty include noise (except for Marine Mammals and Sea Turtles where the certainty for this effect is high), changes to energy regimes, and changes in organism energetic expense. EMF is the only effect that has low certainty consistently across all ecosystem components. Only those potential effects with high certainty are listed in the decision tree; where certainty is low, it may be impossible to detect any effect at this magnitude.

13.2. Component Decision Trees for Block Island Test Case

13.2.1. Component Decision Tree for Benthic Habitat and Resources

Determine which effects to Benthic Habitat and Resources need to be monitored:

The energy resource is

Wind……………………………………………………………………………………………………… Go to A

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice……………………………………………… Go to A1

A1. The stage of the monopile, tripod, or lattice wind turbine project is

Construction…………………………………………………………………… W1, W2

Operation……………………………………………………………………… W1, W2, W3

See the Monitoring Protocols for Benthic Habitat and Resources for indicators and strategies to monitor these effects.

W1. Scour and/or deposition

W2. Changes in benthic community composition

W3. Increase in hard bottom habitat

13.2.2. Component Decision Tree for Fisheries Resources and Fishing Activity

Determine which effects to Fisheries Resources and Fishing Activity need to be monitored:

The energy resource is

Wind……… Go to A

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice OR Gravity.. Go to A1

A1. The stage of the monopile, tripod, lattice, or gravity wind turbine project is

Construction……………………………………………………………X1, X2, X5

Operation…………………………………………………………………… X1, X2, X3, X5

See the Monitoring Protocols for Fisheries Resources and Fishing Activity for indicators and strategies to monitor these effects.

X1. Meso-scale changes to abundance and distribution (disturbance)

X1a. The species of concern are finfish

X1b. The species of concern are crustaceans or rock fish

X2. Habitat alteration/community composition: Micro-scale changes to abundance and distribution — finfish

X3. Reef effects

X5. Spatial use of fishing activity

Component Decision Tree for Avian Species

Determine which effects to Avian Species need to be monitored:

The energy resource is

Wind…… Go to A

A. The stage of the wind energy project is

Construction…………………………………………………………………………… Go to D

Operation………………………………………………………………………………… Go to D, Go to E, Y8

D. The target species are

Easily disturbed, cryptic……………………………………………………………… Y3, Y4

E. The target species are

Diurnal…………………………………………………………………………………………… Y5, Y6

See the Protocols for Monitoring Avian Species below for indicators and strategies to monitor these effects.

Y3. Aerial surveys using high definition video

Y4. Aerial surveys using digital still photography

Y5. Radar surveys

Y6. Visual surveys

Y8. Remote detection system

13.2.3. Component Decision Tree for Marine Mammals

Determine which effects to Marine Mammals need to be monitored:

The energy resource is

Wind.. Go to A

A. The stage of the wind energy project is

Construction..Z1, Z2, Z3, Z4, Z5

Operation... Z1, Z2, Z3, Z4, Z5

See the Protocols for Monitoring Marine Mammals below for indicators and strategies to monitor these effects.

Z1. Visual surveys

Z2. Passive acoustic monitoring

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Component Decision Tree for Sea Turtles

Determine which effects to Sea Turtles need to be monitored:

The energy resource is

Wind………………………... Go to A
.

A. The wind turbine foundation is

Lattice ………………... Go to A2

A2. The stage of the lattice structure or gravity foundation wind project is

Construction….………..………... Z1, Z3, Z4, Z5, Z9

Operation………………………………………………………………… Z1, Z3, Z4, Z5

See the Protocols for Monitoring Sea Turtles below for indicators and strategies to monitor these effects.

Z1. Visual surveys

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Z8. ROV Surveys

14. APPENDIX B. RI/MA WIND ENERGY AREA TEST CASE

Appendix B presents the relevant sections of the Effects Decision Tree, Effects Scenario, and the Component Decision Trees that were used in selecting relevant protocols for the Commercial Wind Farm test case (Section 11).

14.1. Effects Decision Tree for RI/MA Wind Energy Area Test Case

The energy resource is

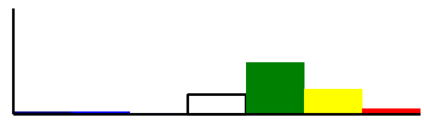
Wind………………………………………………………………………………………………… Go to A

A. The wind turbine foundation is

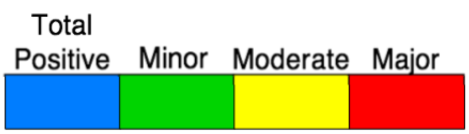
Tripod/Lattice………………………………………………………………………………… Go to A3

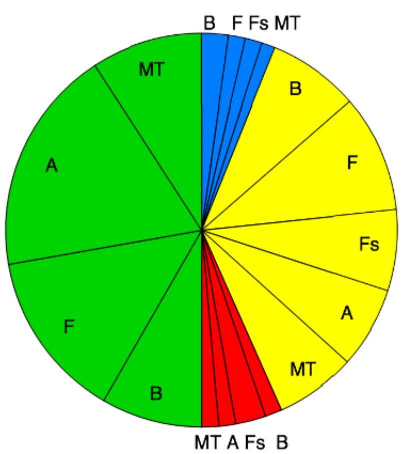
A3. The tripod/lattice wind turbine project scale is

Commercial/Multiple commercial………………… Go to E2



Effects Scenario E2—Wind Turbine Developments Involving Pile Driving





This scenario includes monopile wind turbine developments and jacketed- or tripod-mounted turbines at development Scales 2 and 3. If the proposed development will not utilize pile driving to install the jacketed or tripod structures, then Scenario E3 is more appropriate. The effects that make this scenario unique are the presence of turbines above the water surface, the piles drilled into the seabed, and the noise associated with this activity. Therefore, the expected major effects include noise, scour and/or deposition around the structures, displacement or attraction to structures, and loss of access to mobile gear fishing grounds. Notable moderate effects include resuspension of pollutants, loss of access to recreational and fixed gear fishing grounds, decreased catchability (Fishing Activity), damaged/lost fishing gear, and collisions and strikes for Avian Species, Marine Mammals and Sea Turtles. Reef effects are likely for Benthic Habitat and Resources and Fish Species at these developments. At this stage of knowledge and study, the profile of effects between Scale 2 and Scale 3 differs primarily in the level of certainty (medium/high for Scale 2 and low for Scale 3).

14.2. COMPONENT DECISION TREES FOR RI/MA WIND ENERGY AREA TEST CASE

14.2.1. Component Decision Tree for Benthic Habitat and Resources

Determine which effects to the Benthic Habitat and Resources need to be monitored:

The energy resource is

Wind…… Go to A

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice…………………………………………………………. Go to A1

A1. The stage of the monopile, tripod, or lattice wind turbine project is

Construction……………………………………………………………………… W1, W2

Operation……………………………………………………………………… W1, W2, W3

See the Monitoring Protocols for Benthic Habitat and Resources for indicators and strategies to monitor these effects.

W1. Scour and/or deposition

W2. Changes in benthic community composition

W3. Increase in hard bottom habitat

14.2.2. Component Decision Tree for Fisheries Resources and Fishing Activity

Determine which effects to Fisheries Resources and Fishing Activity need to be monitored:

The energy resource is

Wind... Go to A

A. The wind turbine foundation is

Monopile OR Tripod OR Lattice OR Gravity.. Go to A1

A1. The stage of the monopile, tripod, lattice, or gravity wind turbine project is

Construction...X1, X2, X5

Operation..X1, X2, X3, X5

See the Monitoring Protocols for Fisheries Resources and Fishing Activity for indicators and strategies to monitor these effects.

X1. Meso-scale changes to abundance and distribution (disturbance)

X1a. The species of concern are finfish

X1b. The species of concern are crustaceans or rock fish

X2. Habitat alteration/community composition: Micro-scale changes to abundance and distribution — finfish

X3. Reef effects

X5. Spatial use of fishing activity

Component Decision Tree for Avian Species

Determine which effects to Avian Species need to be monitored:

The energy resource is

Wind……… Go to A

A. The stage of the wind energy project is

Construction……………………………………………………………………… Go to D

Operation…………………………………………………………………………… Go to D, Go to E, Y8

D. The target species are

Easily disturbed, cryptic…………………………………………………………… Y3, Y4

E. The target species are

Diurnal………………………………………………………………………………… Y5, Y6

See the Protocols for Monitoring Avian Species below for indicators and strategies to monitor these effects.

Y3. Aerial surveys using high definition video

Y4. Aerial surveys using digital still photography

Y5. Radar surveys

Y6. Visual surveys

Y8. Remote detection system

Component Decision Tree for Marine Mammals

Determine which effects to Marine Mammals need to be monitored:

The energy resource is

Wind…………………………………………………………………………………………………… Go to A

A. The stage of the wind energy project is

Construction………………………………………………………………… Z1, Z2, Z3, Z4, Z5

Operation……………………………………………………………………… Z1, Z2, Z3, Z4, Z5

See the Protocols for Monitoring Marine Mammals below for indicators and strategies to monitor these effects.

Z1. Visual surveys

Z2. Passive acoustic monitoring

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Component Decision Tree for Sea Turtles

Determine which effects to Sea Turtles need to be monitored:

The energy resource is

Wind……………………...Go to A

A. The wind turbine foundation is

Lattice ………………... Go to A2

A2. The stage of the lattice structure or gravity foundation wind project is

Construction….………..………..Z1, Z3, Z4, Z5, Z8

Operation……………………………………………………………….Z1, Z3, Z4, Z5

See the Protocols for Monitoring Sea Turtles below for indicators and strategies to monitor these effects.

Z1. Visual surveys

Z3. Marine mammal observers

Z4. Stranding response networks

Z5. Tagging

Z8. ROV Surveys

15. APPENDIX C. PROJECT ADVISORY COMMITTEE

Management Team	
Jennifer McCann	URI Coastal Resources Center/RI Sea Grant
Grover Fugate	RI Coastal Resources Management Council
Dr. John King	URI Graduate School of Oceanography
Dr. Peter Paton	URI Department of Natural Resources Science
Dr. Deborah French-McCay	RPS-ASA, Inc.
Dr. Malcolm Spaulding	URI Ocean Engineering

Topic Leads	
Dr. Sarah Smith	URI CRC/RI Sea Grant
Dr. Emily Shumchenia	URI GSO
Kris Winiarski	URI Department of Natural Resources Science
Dr. Robert Kenney	URI GSO
Dr. Malia Schwartz	URI Department of Fisheries, Aquaculture, and Veterinary Science
Danielle Reich	RPS-ASA, Inc.
Melanie Schroeder	RPS-ASA, Inc.
Dr. Rod Mather	URI Dept. of History
Michelle Carnevale	URI CRC/RI Sea Grant

Project Advisory Committee	
Aileen Kenney	Deepwater Wind
Amy Van Atten	NOAA/Northeast Fisheries Science Center
Andrew B. Gill	Cranfield University (UK)
Annette Grilli	URI Ocean Engineering
Brian Hooker	BOEM
Brian Oakley	URI Geosciences
Caleb E. Gordon	Normandeau Associates
Carrie Upite	NMFS/NERO
Chris Boelke	NMFS Northeast Regional Office
Chris Littlefield	The Nature Conservancy
Chris Madden	NatureServe
Daniel Morris	NMFS Northeast Regional Office
Dave Beutel	RI Coastal Resources Management Council
David Bigger	BOEM
Debi Palka	NMFS/NEFSC
Doug Pfeister	Offshore Wind Development Coalition
Dr. Eric Rexstad	Univ. of St. Andrews, Scotland
Dr. James Allan	William Self Associates
Ed LeBlanc	U.S. Coast Guard
Eileen Graham	Applied Science Associates
Frank Cantelas	NOAA, OER
Frank Thomsen	CEFAS

Heidi Souder	NREL/Marine Hydrokinetics
Jack Musick	VIMS
James Price	BOEM/Envir. Sciences Branch
Jason Osenkowski	RI DEM
Jeremy Collie	URI GSO
Jill Rowe	Applied Science Associates
John Jenson	URI Dept. of History
John Primo	BOEM/Envir. Sciences Branch
Jon Boothryod	RI State Geologist
Judy Soule	NatureServe
Kaety Hildebrand	Oregon Sea Grant
Karen Adams	US Army Corps
Kathy Goodin	NatureServe
Keith Kirkendall	NOAA Northwest Region
Mark Finkbeiner	NOAA/CSC
Mary Boatman	BOEM
Matt Nixon	Maine State Planning Office
Mel Cote	U.S. EPA
Michael Rasser	BOEM
Molly Lutcavage	UMASS- Amherst
Phil Colarusso	EPA
Rebecca J. Allee	NOAA/CSC
Robert DeSista	U.S. Army Corps of Engineers
Ru Morrison	NERACOOS

Russ Brown	NOAA Northeast Fishery Science Center
Sally McGee	The Nature Conservancy
Sarah Henkel	Oregon State University
Scott McWilliams	URI, Dept. of Natural Resources Science
Susan Tuxbury	NMFS Northeast Regional Office
Tabor Allison	American Wind Wildlife Institute (AWWI)
Thomas E. Bigford	NOAA/NMFS/Office Hab. Cons.
Thomas French	Division of Fisheries and Wildlife
Todd Callaghan	MA Office of Coastal Zone Management
Tom Noji	NOAA Northeast Fisheries Science Center
Tony Fox	Univ. of Aarhus, Denmark
Victor Mastone	Mass. Board of Underwater Archaelogical Resources
Victoria R.C. Cornish	Marine Mammal Commision
Walt Musial	NREL/Natl. Wind Tech. Ctr.

16. APPENDIX D. AVIAN SPECIES – DETAILED STUDY DESCRIPTIONS

Summary of protocols for ship-based line transect surveys, aerial strip-transect surveys, and high-definition videography based on protocols developed by Camphuysen et al. (2004).

SHIP-BASED SURVEY PROTOCOLS

- Individuals or flocks recorded in distance bins (A = 0-50m, B = 50-100m, C =101-200m, D = 201-300m, E 300+m).
- Ship size: a stable platform ranging from 20 to 100 m in length.
- Ship speed: recommended at 10kts (range 5 to 15kts).
- Survey time intervals: observations are continuous, but pooled into 1 min (small study area) to 10 min (large study areas) time increments, preferred time increment is 5 min.
- Observer position: bow of ship at a height of 10m above sea level, ranging 5-25m.
- Observers: at least two observers. A third observer may be recommended to scan well ahead of the ship when species are present which are easily disturbed or when conditions are difficult (e.g. very cold, rough seas) where it is important for observers to take regular breaks.
- Detections: by naked eye supplemented with binoculars for disturbance prone species (e.g., loons, seaducks).
- Survey conditions: no observations in sea state 4 or higher, not useable for marine mammals in sea state >3.
- Data recording: spatially explicit observations tied to GPS location of individual or flock coordinates.
- Birds are counted on both sides of the ship when feasible (glare is often an issue on one side of the ship).
- Record fishing boats or other human activity attracting or displacing birds.
- Flying birds are recorded by taking a ‘snapshot’ at defined intervals in a 300m x 300m box.
- Flying birds are recorded in defined altitude bands.
- Survey transects range from 0.5 nm to 2 nm apart.

AERIAL-SURVEY PROTOCOLS: VISUAL-BASED OBSERVERS

- Transect width: 1000m, with three distance bands: 44-163 m, 164-432 m, and 433 -1000m).
- Aircraft: twin engine with high wings.
- Number of pilots: two for safety considerations.
- Aircraft speed: 185 km per hr.
- Aircraft altitude: 80 m altitude.
- Observer position: one on both sides of aircraft, with an inclinometer or marked wing struts to measure declination.

- Observers: two competent, trained observers with GPS (recorded at least every 5 sec) and digital voice recorder devices.
- Detections: by naked eye.
- Survey conditions: No observations in sea state higher than 3.
- Data recording: exact time of observations tied to GPS location to nearest 2 seconds.
- Sampling units: individuals or flocks of birds.
- Ground observer following plane remotely with tracking software to notify Coast Guard in case of incident.
- Crew recommended to undergo aircraft ditch training to prepare for incidents.
- Crew wears survival suits during winter surveys and flight suits during summer surveys.

AERIAL HDVIDEOGRAPHY AND STILL PHOTOGRAPHY

- Transect Spacing: recommended at least 2 km apart.
- Transect width: variable depending on optics used
- Number of pilots: two for safety considerations.
- Aircraft: multiengine if surveys are > 3 miles offshore
- Aircraft speed: variable depending on aircraft and optics used
- Aircraft Altitude: variable depending on aircraft and optics used
- Survey conditions: No observations in sea state higher than 3.
- Data recording: observations tied to GPS location to nearest 2 seconds.
- Sampling units: single or flocks of birds.

17. APPENDIX E. MARINE MAMMALS AND SEA TURTLES – DETAILED STUDY DESCRIPTIONS

Marine Mammals & Sea Turtles Additional Protocol: Stress Hormone Assessment

MONITORING OBJECTIVE: Quantification of physiological stress related to disturbance from ORED

Indicator(s) of the impact	Elevated levels of stress-related corticosteroid hormones in animals subject to disturbance from activities associated with ORED development.
Methodology or Technique to Collect Data	Collecting biological samples from whales (fecal matter or blow samples) to evaluate stress hormones
Description of Methodology or Technique(s) to Collect Data	• Measurement of levels of corticosteroid hormones and/or their metabolites is a standard biomedical technique. • Data collection can be by collecting fecal or blow samples from free-swimming whales. • Sampling could be in a control-impact design or a gradient design along a continuum of distances from a potential disturbance. (See Appendix E for more details)
Methodology for Analyzing data	Standard hormone bio-assays; statistical comparison of levels between control and treatment groups.
Frequency and Duration	To be defined by the number of samples necessary to obtain statistically meaningful results.
Spatial Scale	Project-specific, depending on the ranges at which potential disturbance has been detected by other monitoring studies.
Other Considerations **(E.g. Advantages or Disadvantages)**	Stress hormone assessment on free-swimming marine mammals is a relatively new method that to date has only been applied to a couple of large whale species, however those are usually the species of the greatest conservation concern.
Relationship to other protocols	This methodology is more focused research that would not likely be employed until other monitoring (e.g., surveys, PAM) has detected changes in distribution related to the project. Also see the tagging protocol (Protocol 5). A sort of controlled exposure experiment could be conducted by sampling from animals tagged with DTAGs or similar tags that monitor received levels of sound, and correlating stress hormone levels with noise exposures.
Cost (High, Medium, Low)	Medium
Data Format	To be determined.
Data Output	Stress hormone concentrations from samples collected in control and impact areas or from along an exposure gradient.
Examples where this	Rolland et al. 2007; Hogg et al. 2009; Rolland et al. 2012 (See Appendix E)

methodology has been used	

1. Marine Mammal/Sea Turtles

Visual Surveys

Detailed Description of methodology/methodologies:

Visual surveys entail searching by trained observers for target species. Typically observers are aboard ships and/or aircraft following pre-defined track-lines covering an area of interest, but surveys can be land-based for a specific focus (turtle nesting, pinniped rookeries or haul-outs). During an at-sea survey, there is continuous recording of platform parameters (date, time, location, heading, speed, altitude), environmental parameters (visibility, sea state, weather, water temperature, depth, oceanographic data), and all sightings (species, numbers, behaviors). Visual survey design and methodology is well-established, and can be modified based on objectives (e.g., distribution patterns over a broad region vs. behavioral responses to a potential stressor). There are more recent efforts to conduct aerial surveys using high-definition photography or video; some earlier efforts to use sophisticated multi-spectral sensors for aerial marine mammal surveys have apparently not been successful. In some locations with the right characteristics, visual and/or photographic observations by land-based observers are possible.

The decision as to whether to employ visual surveys or passive-acoustic monitoring for any particular project will be site-specific, depending on previous information on species present and their expected densities. Some species cannot be monitored by passive acoustics because they do not typically vocalize underwater (sea turtles, many pinnipeds). On the other hand, some species are difficult to survey from one or more types of survey platforms—, e.g., harbor porpoises tend to be inconspicuous and are difficult to see, and sea turtles are rarely detected during boat-based surveys. Expected density is also a factor. For example, boat-based surveys and passive-acoustic sensors were both used for assessing harbor porpoise relative abundance in the two wind farms off Denmark (see below). Both methods were used at Horns Rev, however at Nysted porpoise densities were known to be substantially lower, so that boat-based surveys would be unable to generate sufficient sightings and the statistical power to detect differences would have been inadequate.

Examples where this methodology has been used:

Most baseline assessment work has involved aerial and/or shipboard surveys, however it should be reiterated here that planning for "monitoring" presumes that the basic assessment work for site selection has already been completed. The Cetacean and Turtle Assessment Program (CETAP, 1982), conducted by URI in 1978–1982, was the first really extensive baseline assessment in the U.S. Atlantic. It included aerial and shipboard surveys of the continental shelf waters from North Carolina to Nova Scotia to assess the species diversity, distribution, abundance, and seasonality of whales, dolphins, porpoises, and sea turtles off the northeastern U.S.—related to the environmental assessment process for offshore petroleum exploration. The 1994 amendments to the MMPA mandated periodic assessments of all marine mammal stocks under U.S. jurisdiction (Waring et al., 2010; Allen and Angliss, 2011; Caretta et al., 2011). Since that time, NMFS has been conducting aerial and shipboard surveys of the entire U.S. Exclusive Economic Zone in both the Atlantic and Pacific. Because of the ranges of some Pacific dolphin species, the NMFS ship surveys in the Pacific encompass an area from the west coast of the U.S.

and Mexico to Hawaii. Because an area that large can only be surveyed with very sparse coverage, NMFS has been in the forefront of efforts to use habitat modeling to increase the extent and statistical precision of the resultant abundance estimates (Forney 2000; Ferguson et al., 2006a, 2006b; Redfern et al., 2006; Barlow et al., 2009; Becker et al., 2010).

Visual surveys, both aerial and shipboard, are being used for monitoring of naval training operations in a variety of locations (Florida, North Carolina, Gulf of Mexico, southern California, Hawaii, Northern Marianas Islands), however the survey reports are still classified for official use only and not publicly available. Visual surveys around a construction site can be used to relay information about animals in the vicinity to managers and on-board MMOs.

Vessel-based visual surveys were used for monitoring harbor porpoises and seals within and near the turbine array at the Horns Rev wind farm in Denmark (Teilmann et al., 2006a, 2006b). Similar surveys were conducted for porpoises, common dolphins, and minke whales in Scotland (Thompson et al., 2010). At the Nysted wind farm in Denmark, boat surveys to monitor porpoises were not conducted because the densities were known to be too low for visual surveys to generate enough sightings and have enough statistical power to detect changes. Some aerial surveys were flown to monitor the numbers of seals hauled out at a few specific sites nearby (Teilmann et al., 2006b; Edrén et al., 2010). In addition, land-based observations to monitor numbers of seals hauled out at a seal sanctuary near Nysted were conducted, using both visual observers and a remote time-lapse video system mounted on top of a tower overlooking the haul-out beach at the sanctuary (Teilman et al., 2006b; Edrén et al., 2010).

Both land- and vessel-based behavioral observations have been utilized in studies of the potential effects of noise on the behavior of baleen whales. Migrating gray whales were tracked by observers in elevated on-shore locations in California (Malme et al., 1984). Whales tended to divert around a vessel playing industrial noise (i.e., sounds associated with petroleum exploration). Humpback whale behavior in Hawaii was studied in response to low-frequency sounds associated with the Acoustic Thermometry of Ocean Climate (ATOC) project, including both simulated (Frankel and Clark, 1998) and actual ATOC signals (Frankel and Clark, 2000). In both cases it was difficult to show any effect of the ATOC signal; intensive statistical analysis could demonstrate subtle changes in surfacing behavior correlated with received levels, although the presence of nearby vessels had a much clearer effect on whale behavior. The authors cautioned about extrapolating their results to infer biologically significant effects on the whales; that same caution has been repeated more generally by others (NRC, 2000, 2005; Thomsen et al., 2011).

2. Marine Mammal/Sea Turtles

Passive Acoustic Monitoring

Detailed Description of methodology/methodologies:

The data output from passive-acoustic monitoring will depend heavily on the sensors and sampling methodology employed. The "holy grail" of passive-acoustic studies is the ability to generate density estimates from PAM data alone, however that capability does not yet exist except under restricted circumstances. Some studies have combined visual data from shipboard surveys and simultaneous PAM data from towed arrays in deriving density estimates for sperm whales (e.g., Laran et al., 2010). Kyhn et al. (2012) developed a method for estimating harbor porpoise density from a small array of PAM sensors, however calibrating the method again required concurrent visual data.

PAM sensors with continuous recording capability can generate extremely large amounts of raw digital data (frequency and intensity vs. time)—potentially terabytes of data—that will need to be analyzed and archived. Cornell's pop-ups (see below) can store up to 80 gigabytes per deployment. Continuous data can be analyzed for all species that might be present and whose vocalizations fall within the frequency range recorded. Data from units such as the Cornell ABs will be useful only for those species

A variety of metrics can be used for quantifying PAM results that can then be utilized in a BACI or other analysis, presuming that density estimates will not be possible within the near future. Actual tracks of vocalizing individuals can be compared between control and impact areas or times. Risch et al. (2012) used the number of minutes per day with humpback whale song detected. The metric used by Mussoline et al. (2012) was the number of right whale up-calls per day per MARU. The PAM studies of harbor porpoises in Danish wind farms used several different metrics (Carstensen et al., 2006; Teilmann et al., 2006a; Tougaard et al., 2009), including "porpoise-positive minutes (minutes with clicks recorded), waiting time between encounters (detections of sets of clicks), waiting time from the end of pile-driving to the first detection, duration of encounters, and number of clicks per porpoise-positive minute.

Detailed Description of methodology/methodologies:

Passive-acoustic monitoring (PAM) of sounds from animals in or near the project area can be used for assessing the distribution, relative abundance, and behavior of animals in the study area and monitoring noise from the activity. PAM can be utilized for baseline assessment work (i.e., to determine which species might be present in a project area and their relative abundance), however it should be reiterated here that planning for "monitoring" presumes that the basic assessment work for site selection has already been completed. PAM essentially consists of listening for sounds produced by submerged animals, identifying the vocalizing species, and either recording the sounds directly or archiving summary data on species detections. PAM is also useful for monitoring sounds produced by the project activities (construction, operation, decommissioning, vessels, etc.) for better assessment of potential impacts, creation and ground-truthing of acoustic propagation models, and verification of any required noise mitigation techniques.

PAM methods include a wide variety of potential sensors, including bottom-mounted hydrophone arrays, anchored moorings, hydrophones or hydrophone arrays towed behind vessels, or expendable sonobuoys deployed from aircraft or ships. Bottom-mounted arrays (more or less permanent installations) can be connected to shore facilities via cable and provide the capability for continuous, full-spectrum monitoring and recording of all sounds received, as with the Navy's SOSUS (Sound Surveillance System) submarine-tracking arrays (http://www.navy.mil/navydata/cno/n87/usw/issue_25/sosus.htm). Such facilities are likely to be far too expensive for use in routine monitoring of MRE projects. For more typical moored systems, the two primary units used by Cornell University's Bioacoustics Research Program (http://www.birds.cornell.edu/brp) are good examples of types and capabilities. Their most commonly used sensors are known as Marine Acoustic Recording Units (MARUs, often referred to as "pop-ups"). MARUs are deployed at depth, connected to an anchoring system by an acoustic release. The unit processes, filters, and records sounds, with their effective duration determined by a combination of memory capacity, on-board battery life, and sampling schedule. The unit is periodically recovered by triggering the acoustic release, the data are downloaded for subsequent analysis, and the unit can then be re-deployed with fresh batteries for another sampling period. The other type of sensor is the Auto-Detect Buoy (AB). In addition to the sensor package at depth, the AB has a surface buoy that can transmit information in near real-time back to a shore station via satellite or cellular telephone link. The uplink bandwidth is insufficient for transmitting continuous data or complete sound spectra. The unit includes on-board hardware and software that continuously monitor sounds and automatically classify particular sounds (e.g., right whale up-calls). When the AB detects a probable right whale call, it transmits a message back to shore that includes a short spectrum including the call, which is then reviewed and confirmed by a human operator.

Most PAM sensors detect only presence/absence within some range of the sensor, which varies with source level and local acoustic propagation conditions. Sensors, as well as the associated processing hardware and software, can vary widely in their capabilities. Sensors need to be selected for the expected frequency ranges of the species that require monitoring, which can range from as low as 10-12 HZ for blue and fin whale vocalizations to as high as 150-200 kHz or more for echolocation pulses in toothed whales (Thomson and Richardson, 1995). Some sensors have the capability to provide bearings to targets; two or more intersecting bearings provide source location. An array of multiple sensors can also provide locations from arrival time differences or other signal post-processing. A large enough array of PAM sensors can provide continuous tracking of vocalizing individuals, or other noise sources (e.g., ships moving through the area).

The decision as to whether to employ passive-acoustic monitoring or visual surveys for any particular project will be site-specific, depending on previous information on species present and their expected densities. Some species cannot be monitored by passive acoustics because they do not typically vocalize underwater (sea turtles, many pinnipeds). On the other hand, some species are difficult to survey from one or more types of survey platforms—e.g., harbor porpoises tend to be inconspicuous and are difficult to see, and sea turtles are rarely detected during boat-based surveys. Expected density is also a factor. For example, boat-based surveys and passive-acoustic sensors were both used for assessing harbor porpoise relative abundance in the two wind farms off Denmark (see below). Both methods were used at Horns Rev, however at Nysted porpoise densities were known to be substantially lower, so that boat-based surveys would be unable to generate sufficient sightings and the statistical power to detect differences would have been inadequate.

Examples where this methodology has been used:

At both the Horns Rev and Nysted wind farms in Denmark, studies used arrays of archival acoustic detectors designed specifically for harbor porpoise echolocation clicks (Carstensen et al., 2006; Teilmann et al., 2006a, 2008; Diederichs et al., 2008; Tougaard et al., 2009; Clausen et al., 2010; Brandt et al., 2011) in a BACI design. Boat-based visual surveys were also used for monitoring harbor porpoises (and seals) within and near the turbine array at Horns Rev, but at Nysted boat surveys were not conducted because porpoise densities were known to be too low for visual surveys to generate enough sightings and statistical power to detect changes (Teilmann et al., 2006a). Thompson et al. (2010) similarly used PAM for monitoring harbor porpoises and bottlenose dolphins during pile-driving for two wind turbine installations in Scotland. PAM sensors, both fixed moorings and towed arrays, have been deployed in association with several naval exercise monitoring programs. In addition, the Navy operates several fixed underwater acoustic ranges where effects on marine mammals can be studied directly. Tyack et al. (2011) reported the results of one study looking at the effect of navy sonar on behavior of deep-diving whales at the AUTEC (Atlantic Underwater Test and Evaluation Center) range in the Tongue of the Ocean in the Bahamas.

There are two offshore terminals for delivery of liquefied natural gas (LNG) in operation in Massachusetts Bay east of Boston, Northeast Gateway and Neptune. A specialized LNG tanker connects to a submerged buoy, which is moored to the bottom and connected by a flexible riser to a subsea pipeline. A regasification plant aboard the tanker warms the LNG, converting it from liquid to gas and feeding it directly into the pipeline and the regional distribution system. The Incidental Harassment Authorizations (IHAs) for operating both terminals (NMFS, 2010b, 2010c) requiring continuous maintenance of a Research Passive Acoustic Monitoring (RPAM) system, which consists of 29 PAM moorings, consisting of 19 pop-ups that are retrieved, downloaded, and re-deployed about every 90 days and 10 ABs (programmed to detect, identify, and count right whale up-calls) permanently moored down the center of the primary shipping lanes.

Risch et al. (2012) made use of the Massachusetts RPAM system in an opportunistic study of noise effects on humpback whales in the Stellwagen Bank National Marine Sanctuary (SBNMS). For 11 days in the fall of 2006, the pop-ups in the Sanctuary detected sounds from a fisheries acoustics experiment being conducted about 200 km away in the Gulf of Maine. They compared humpback whale songs recorded on the same pop-up array during the same 33-day periods (11 days before, 11 during, and 11 after) in 2006, 2008, and 2009 to show a statistically significant decrease in singing while the distant acoustic source was transmitting. While the study showed a detectable effect of anthropogenic sound on humpback whale behavior, it did not address the question of whether that effect was biologically significant at either the individual or population level.

3. Marine Mammal/Sea Turtles

Marine Mammal Observers

Detailed Description of methodology/methodologies:

Marine Mammal Observers are trained observers posted on board vessels in an active construction or operational area. MMOs can be posted aboard construction vessels, cable-laying ships, service vessels and others transiting between the work area and shore facilities, or dedicated MMO vessels. MMOs can be dedicated individuals with no other responsibilities, or they can be normal crew-members who have been provided with specialized training. The primary objective often is mitigation—detection of animals in potential zones of injury and shutting down operation and/or stopping or diverting vessels.

Examples where this methodology has been used:

The proposed monitoring and mitigation plan in the Cape Wind EIS (MMS, 2009) requires MMOs to monitor an exclusion zone around any seismic survey vessel (500 m) or pile-driving (750 m). The IHA issued for pile-driving for a bridge construction in San Francisco (NMFS, 2003) specified 3 MMOs per site and a 500-m safety zone. An IHA issued for a seismic survey in the Chukchi Sea west of Barrow, Alaska (NMFS, 2010a) required trained MMOs on both the survey vessel and separate monitoring vessels and exclusion zones based on modeled ranges where received sound levels were predicted to be loud enough to cause injury (permanent hearing damage). The Northeast Gateway and Neptune LNG terminal IHAs required MMOs on multiple vessels during construction, but only during major repair activities after construction. During terminal operations, MMOs (or MMO training for bridge crews and lookouts) are required only for the LNG tankers (dynamic positioning thrusters used while at the terminal are the loudest sound source). During naval exercises, the MMO role is typically filled by the lookouts who are always posted while a vessel is at sea. Under its Integrated Comprehensive Monitoring Plan (DON, 2009), the Navy plans to conduct experiments with independent MMOs (trained, experienced biologists) to evaluate the effectiveness of Navy lookouts.

4. Marine Mammal/Sea Turtles

Stranding Networks

Detailed Description of methodology/methodologies:

There are regional stranding response networks presently in operation along all coasts of the U.S., comprised of multiple cooperating organizations coordinated by the relevant NMFS Regional Office (Anonymous, 2010). Within NMFS there are separate programs and staff dealing with marine mammal and sea turtle stranding response, however the network member organizations are by and large the same for both. Each cooperating organization typically has a collection of trained staff and volunteers who respond to reported strandings (alive or dead) of marine mammals or sea turtles within their area of responsibility. Responders are required to collect basic information (“level A data”) on the stranded animal(s), including date, location, species identification, number of animals, sex, condition of the animal, basic measurements, and whether there is evidence of human interaction. More detailed data may be collected at the discretion of NMFS and the organization, given logistics, funding, personnel, etc. For some regions (e.g., Cape Cod, Massachusetts—Bogomolni et al., 2010) or species (e.g., North Atlantic right whales—Moore et al., 2007) there are substantial, on-going efforts to determine cause of death in as many mortality events as possible.

There should be enhanced stranding investigational response in areas of potential or on-going development that might detect injuries caused by construction or other activities. This would include support for recovering floating carcasses detected by monitoring surveys or MMOs, and for detailed necropsies and pathology studies of all stranded or recovered carcasses where there is any evidence for the mortality to have been related to the MRE project. Given sufficient standardization of response and data collection, a BACI analysis of stranding data could be possible.

Examples where this methodology has been used:

Stranding network members are not specifically involved in monitoring of construction or other industrial activities at the present time, beyond collecting level A data as required by their authorizations from NOAA. Most response organizations are not funded at the level necessary for at-sea carcass recoveries or to ensure the detailed post-mortem analyses that would be necessary for forensic cause-of-death determinations. The annual marine mammal stock assessments (Waring et al., 2010; Allen and Angliss, 2011; Caretta et al., 2011) do make use of human-interaction data from the stranding networks to supplement fisheries-observer data in estimating human-related mortality rates.

5. Marine Mammal/Sea Turtles

Tagging

Type of Data Output Required/Data Format:

The type of data resulting from tagging studies can be extremely variable, and will be dependent upon the type of tags employed. All tagging will result in some level of geospatial data—locations of the tagged individual at particular times. Depending on the tag, these can range from simply deployment and recovery locations for flipper tags to small numbers of locations per day for satellite or geo-locator tags, to detailed movement tracks for GPS archival tags. Telemetry tags with depth sensors to monitor diving behavior can provide simple data summaries (e.g., number of dives in the previous 24 hr, maximum depth) for tags with restricted reporting bandwidth to detailed, continuous dive profiles for days to months in the case of archival tags. Methods have been developed for taking the depth and accelerometer data from DTAGs and deriving 3-dimensional graphics or even animations of the submerged foraging behavior of tagged whales (Ware et al., 2006).

There are many quantifiable behavioral parameters that can be derived from tagging studies and utilized in statistical analyses, and there have been some attempts at standardization, include a Marine Wildlife Behavioral database developed with Navy funding by URI and Marine Acoustics, Inc. (http://mwbd.edc.uri.edu). For example, just in the category of diving behavior, the parameters include (with the usual mean, median, mode, maximum, minimum, and variability for each) diving rate (number of dives per hour or day), percent time submerged, ascent rate, descent rate, dive depth, dive time, bottom time, surface time, travel speed, ascent angle, descent angle, and others (Shaffer and Costa, 2006; http://mwbd.edc.uri.edu/design.htm).

Detailed Description of methodology/methodologies:

As with stress hormone studies, tagging and telemetry studies straddle the boundary between monitoring and basic research on potential effects of offshore development. Tagging studies may not be planned initially, but might be added on after the results of other monitoring studies indicate that there are some detectable effects of an offshore development.

Tagging methods are extremely variable, with trade-offs between cost, complexity, risk, data return, etc. At one end of the continuum are simple tags that are attached and later recovered or observed one or more times, such as bird bands, flipper tags on seals or sea turtles, fish tags, brands, etc. These would provide little information relative to impacts of offshore construction or industrial activities (although see below for discussion of long-term photoID studies). There are simple VHF radio tags that only transmit a signal, allowing for observers to follow movements. Because radio waves do not penetrate seawater, tags only transmit when the antenna is above the surface—providing basic information on diving/surfacing behavior as long as the tagged animal is within a relatively short range of the receiver. VHF tags require continuous on-scene monitoring to develop good tracking data. There are radio tags that are monitored from Earth-orbiting satellites that do not require continuous monitoring from nearby, however these provide only a small number of locations per day. Telemetry tags record and transmit one or more parameters back to the receiver. A simple telemetry tag is a sonic tag, which can be attached to fishes, mammals, or turtles, that encodes its depth in the acoustic pulse transmitted—these require very short tracking distances. Telemetry tags can also measure water temperature, salinity, light level, location (via light sensors or on-board GPS), received sounds, swimming speed, and movements in all three axes. The amount of data that can be recorded and reported depend on attachment duration, battery life, memory capacity, and data transmission limits. There are archival tags with long-term attachments designed to come off after a predetermined time, then report the stored data via satellite uplink (or be directly downloaded if they can be physically recovered). Some archival tags used on seals drop off at the time of the annual molt and can be recovered from the beach and downloaded. Finally, there are short-term digital archival tags (DTAGS) that attach via suction cups; the short-term deployments allow very high data-recording rates and fine-scale reconstructions of movements in three dimensions.

Tagging is logistically complex and often quite costly. Except for satellite-linked tags, tagging studies require continuous presence at sea in the study area for the duration of the study. Tags can be deployed on large whales without capturing the animal (using methods such as firearm, harpoon, crossbow, air rifle, etc.), but for sea turtles, seals, and many small cetaceans the animal must be captured in order for the tag to be attached—requiring experienced capture teams and veterinary oversight. Tags can be attached to animals that were live-stranded and then rehabilitated, but that introduces an element of chance into the sampling plan and also raises questions about the representativeness of the sample. All tagging of marine mammals and sea turtles requires a marine mammal and/or endangered species scientific research permit issued by the federal government. Permit applications can take over a year to be processed and approved. For some species, there may be reluctance to issue permits for longer-term penetrating tags on endangered species. Much of the recent tagging on right whales and humpback whales has been done using short-term deployments of suction-cup DTAGS.

Photo-identification of individuals can be considered as a tagging method using natural tags or markings (now extended to DNA profiles). Long-term photoID studies provide some of the best data for understanding population-level demographic parameters such as survival and mortality rates, population growth rates, longevity, etc., and assessing long-term population-level effects of environmental perturbations. Those studies are currently underway only with a limited subset of the species in U.S. waters.

Examples where this methodology has been used:

Satellite-tracked radio tagging was conducted on seals at the wind-farm sites in Denmark—on harbor seals at both Horns Rev and Nysted and on gray seals at Nysted (Tougard et al., 2003; Teilmann et al., 2006b). Tagged seals ranged more widely than expected, including the immediate areas of the wind farms, however the tagged animals spent less than 1% of their time within the wind farms. In addition, neither the spatial resolution of the data nor the accuracy of the satellite-generated location data were good enough to test for wind-farm impacts.

Müller and Adelung (2008) used digital archival data-logger tags to reconstruct three-dimensional tracks of harbor seals in the Wadden Sea in Germany. Their tag included a satellite-tracked radio to obtain location data, however the tags had to be recovered in order for all of the other archived data to be retrieved (their tag-recovery rate was around 75%). The tags were attached via epoxy glue to the seals' backs; with a 5-second data-logging interval they were capable of recording for up to 94 days.

Short-term DTAGS with suction cup attachments are being used in an increasing variety of behavioral studies on whales and smaller cetaceans. For example, Friedlander et al. (2009) used DTAGs to study the three-dimensional foraging behavior of humpback whales in the SBNMS, and were able to demonstrate day-night differences in feeding behavior as the whales responded to changes in the vertical distribution and behavior of their prey. Because the DTAG's sensors allow both 3D reconstruction of the whale's track and simultaneous record sounds received at the whale's location, they enable studies to test for effects of various sound sources on whale behavior. Miller et al. (2009) attached DTAGS to sperm whales in the Gulf of Mexico to look at possible behavioral effects from seismic air-gun sounds. Nowacek et al. (2004) used DTAGs on right whales in the Bay of Fundy to study the behavioral effects of playbacks of a large variety of sounds in an attempt to understand their reactions to ships and high frequency of collisions. The whales did not respond at all to ship noise, but responded strongly to an artificial alert signal by immediately ceasing feeding at depth and swimming directly to the surface.

5. Marine Mammal/Sea Turtles

Stress Hormone Assessment

Detailed Description of methodology/methodologies:

It is almost a certainty that monitoring studies at one or more offshore renewable energy developments will show changes in the local distribution or behavior of a marine mammal or sea turtle species related to disturbance from the development. The question that will eventually have to be answered will be whether those impacts are biologically significant and cause for further concern, at either the individual or population level. A good example would be the Risch et al. (2012) study showing relatively subtle changes in humpback whale singing in Massachusetts Bay corresponding in time to a fisheries acoustics experiment 200 km away (see the passive-acoustic monitoring protocol). That study showed a detectable effect of sound on humpback whale behavior, but it could not address whether the effect was biologically significant. While there are a few populations where long-term studies have developed the sort of demographic data that would be necessary for detecting population-level effects (e.g., North Atlantic right whales, Gulf of Maine humpback whales, Sarasota Bay bottlenose dolphins), in most cases population-level studies would be far too large on both spatial and temporal scales to be practical.

Measurement of levels of stress-related corticosteroid hormones and/or their metabolites would be one way to detect and quantify physiological impacts of disturbance at the level of an individual animal. Quantifying stress hormone levels in animals potentially affected and not affected by noise or other disturbance in a BACI design would be a method to directly assess stress caused by construction, decommissioning, or operation of an offshore energy facility. Hormone levels are typically measured using blood samples, which is impractical with free-ranging animals. In addition, the activities necessary to collect the blood samples (e.g., chasing and live captures) are themselves likely to cause significant stress. However, methods have recently been developed for measuring steroid hormones in fecal samples and in breath samples.

Examples where this methodology has been used:

The ability to quantify steroid hormones, including those that are elevated in response to chronic or acute stress, in free-ranging wild marine mammals is relatively new. Rolland et al. (2007) summarized New England Aquarium's successes at measuring levels of reproductive and stress hormones, harmful algal biotoxins, and parasites in fecal samples collected from free-swimming right whales in the Bay of Fundy. Hogg et al. (2009) expanded the potential sampling by successfully measuring reproductive hormone levels in blow (breath) samples from both humpback and right whales.

Rolland et al. (2012) were able to show a correlation between reduced low-frequency shipping noise and lower stress hormone levels in right whales in the Bay of Fundy using post-event analysis of serendipitously collected fecal samples and ambient noise recordings. Following the terrorist attacks on September 11th, 2001, the number of commercial ships transiting the Bay of Fundy was substantially reduced for some time. Ambient noise levels were 6 dB re 1 μPa lower than average, with much of the decrease in the <150-Hz range dominated by ship noise. At the same time there was a measureable decrease of levels of stress-related hormone metabolites in fecal samples from right whales.

6. Marine Mammal/Sea Turtles

Underwater Photography Surveys

Detailed Description of methodology/methodologies:

Underwater cameras are positioned near base of structure(s) slated for removal and can record 24-hour activity around structure to identify presence of "resident" animals. Analysis of data is direct, as identification of a resident marine mammal or sea turtle will trigger mitigation protocols. Considered best methodology because of accuracy, likely due to its unobtrusiveness.

Examples where this methodology has been used:

Underwater photography was used by Rosman et al. (1987) to study incidence and behavior of sea turtles around natural and artificial reef structures, and concluded that this method was superior to submersible or diver surveys in identifying turtles. This is likely due to its unobtrusiveness. Photographs often showed turtles lying on the seafloor within the confines of the camera assembly. More turtles were photographed at night than during the day. Individual turtles were sighted multiple times at a single structure (Rosman et al., 1987), suggesting that sea turtles may be “residents” at specific platforms. Further, observation and capture of two loggerheads, *Caretta caretta*, by NMFS at offshore platforms suggest that the turtles hide and/or rest on the bottom under these structures (Klima et al., 1988).

TASK 2.3

REPORT ON THE FRAMEWORK FOR CUMULATIVE IMPACT EVALUATION

This report serves as part of the final deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PC00097, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. A key challenge in siting an energy facility or other commercial or industrial project is balancing the needs of the diverse interests and resources that could be affected by the project while complying with regulatory standards and meeting project objectives. The Siting Evaluation Model (SEM) framework developed in this study provides a useful screening tool for initial offshore renewable energy (ORE) facility siting considerations, and is intended to be used and evaluated in conjunction with other environmental information, regulatory and management priorities, and stakeholder interests.

TASK 2.3

REPORT ON THE FRAMEWORK FOR CUMULATIVE IMPACT EVALUATION (TASK 2.3)

Contributing Authors:

Deborah French McCay, RPS ASA
Danielle Reich, RPS ASA
Eileen Graham, RPS ASA
Melanie Schroeder, RPS ASA
Emily Shumchenia, University of Rhode Island

EXECUTIVE SUMMARY

This report serves as part of the final deliverable for the National Oceanographic Partnership Program (NOPP) Project Number: M10PC00097, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship.

A key challenge in siting an energy facility or other commercial or industrial project is balancing the needs of the diverse interests and resources that could be affected by the project while complying with regulatory standards and meeting project objectives. The Siting Evaluation Model framework developed in this study provides a useful screening tool for initial offshore renewable energy (ORE) facility siting considerations, and is intended to be used and evaluated in conjunction with other environmental information, regulatory and management priorities, and stakeholder interests. The SEM framework allows for the evaluation of the cumulative impacts of multiple offshore developments and other marine uses. The methods developed herein can be applied to ongoing efforts, such as evaluating Wind Energy Areas designated by the Department of the Interior's Smart from the Start Initiative as suitable for offshore wind energy development. The approach may also be extended to other coastal and marine spatial planning efforts to enhance efficient use of the offshore environment, reduce environmental impacts, identify opportunities for shared use, and reduce use conflicts (both between different marine uses and between users and the environment).

The approach for this project was to develop a model whereby input data (geospatial information describing the physical environment, ecosystems, and fish and wildlife populations) can be integrated into a composite map of ecological value, with weighting factors that incorporate relative intrinsic and ecological values. The definition of "ecological value" is based on that used in other recent marine spatial planning valuation efforts, such as an on-going European effort (Derous et al., 2007a,b,c), i.e., the intrinsic value of biodiversity without reference to anthropogenic use. At the species level, the input data are based on measures of aggregation: density, contribution to fitness, productivity, rarity, or uniqueness of attributes. Different criteria, such as the regional/global importance of local species, can change the relative importance of the input layers to the model.

Going a step further than Derous et al.'s (2007a,b,c) approach, we also applied additional weighting factors to address the relative potential impacts of ORE development using the Offshore Renewable Energy Effects Matrix described in the Year 1 deliverable, "Task 1.2 Report on Monitoring the Potential Effects of Offshore Renewable Energy", as well as the "Effects Decision Tree" from the Task 1.5 Final Report.

Categories currently considered in the framework include the benthic ecosystem, the pelagic ecosystem, fish and large invertebrates, birds, sea turtles, marine mammals, and bats. The ecological value model for marine biological resources was tested with an application to the area being considered in the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP). A similar framework is described for addressing human uses of marine resources.

A model calculation tool (the CIM-Eco Calculator) is supplied as an associated deliverable to this report. Using this tool, other weighting schemes may be discussed and evaluated as issues and concerns arise. One of the strengths of the model approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented.

The steps taken for this project were to: 1) Develop methods to design and test a new conceptual framework and approach for a cumulative environmental impact evaluation of offshore renewable energy development; 2) Outline an overall Siting Evaluation Model (SEM) that considers both ecological values and socio-economic (human) uses; 3) Integrate various ecological data inputs into an Ecological Value Model (EVM) considering multiple levels of organization, i.e., first into ecological components (e.g., individual species) and then ecological categories (e.g., birds, fish, benthic ecosystem); 4) Develop methods to quantify weighting factors and uncertainties for compositing ecological categories into an Ecological Value Index (EVI); and 5) Develop methods to quantify weighting factors and uncertainties for modifying the ecological category weights in the EVI related to potential impacts of development in order to generate a Cumulative Impact Model (CIM-Eco), which would become part of the framework for the overall SEM. The results of the CIM-Eco model may be combined with the results of a parallel human use model, CIM-HU, which addresses the impacts of development on human uses of the marine environment. The CIM-HU is based on a Human Use Index (HUI) that would include weightings based on relative (human use) service values. The CIM-Eco and CIM-HU indices form the basis of a Cumulative Use Evaluation Model (CUEM). Using these tools, a decision maker could evaluate the impacts of a development, and ideally, the topology of the composite index (including uncertainties) would identify areas most suitable for ORE development.

The SEM was developed with a focus on ORE siting, but it could be used to evaluate any combination of competing uses of the offshore environment. For example, a decision-maker could use the framework to conduct a cumulative impact evaluation of an ORE development in addition to another type of development, such as an offshore liquefied natural gas (LNG) terminal, by including weightings for both of these projects in a single CUEM, or overlaying individual CUEMs created for each project. It could also be used to evaluate the potential impact of these two projects in conjunction with a variety of other proposed activities, such as changes to shipping lanes or placement of artificial reef materials. The framework allows for a cumulative impact evaluation to be conducted in a quantitative, scientifically-based manner that is open, transparent, flexible, and able to incorporate stakeholder and public input. Use of these tools could substantially enhance Federal, State, tribal, local, and regional decision-making and planning processes.

TASK 2.3

REPORT ON THE FRAMEWORK FOR CUMULATIVE IMPACT EVALUATION

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AMI	Rhode Island –Massachusetts Area of Mutual Interest
AWOIS	Automated Wreck and Obstruction Information System
BOEM	Bureau of Ocean Energy Management
BVM	Biological Valuation Maps
CEQ	Council on Environmental Quality
CIM-Eco	Cumulative Impact Model – Ecological
CIM-HU	Cumulative Impact Model – Human Use
CMECS	Coastal and Marine Ecological Classification Standard
CMSP	Coastal and Marine Spatial Planning
CUEM	Cumulative Use Evaluation Model
DFO	Fisheries and Ocean Canada
EMF	Electromagnetic Field
ENCORA	European Network on Coastal Research
EOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
EVI	Ecological Value Index
EVM	Ecological Value Model
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
HUI	Human Use Index
LE	Lagrangian Element
LNG	Liquefied Natural Gas
MARBEF	Marine Biodiversity and Ecosystem Functioning
MPA	Marine Protected Area
NOAA	National Oceanic and Atmospheric Administration
NOC	National Ocean Council
NOPP	National Oceanographic Partnership Program
OCS	Outer Continental Shelf
ORE	Offshore Renewable Energy
PI	Productivity Index
PPP	Power Production Potential
SAMP	Special Area Management Plan
SEM	Siting Evaluation Model
TCI	Technical Challenge Index
TDI	Technological Development Index
URI	University of Rhode Island

1. INTRODUCTION

A key challenge in siting an energy facility or other commercial or industrial project is balancing the needs of the diverse interests and resources that could be affected by the project while complying with regulatory standards and meeting project objectives. The Siting Evaluation Model (SEM) framework developed in this study provides a useful screening tool for initial offshore renewable energy (ORE) facility siting considerations, and is intended to be used and evaluated in conjunction with other environmental information, regulatory and management priorities, and stakeholder interests. The SEM framework allows for the evaluation of the cumulative impacts of multiple offshore developments and other marine uses. The methods developed herein can be applied to ongoing efforts, such as evaluating Wind Energy Areas designated by the Department of the Interior's Smart from the Start Initiative as suitable for offshore wind energy development. The approach may also be extended to other coastal and marine spatial planning (CMSP) efforts to enhance efficient use of the offshore environment, reduce environmental impacts, identify opportunities for shared use, and reduce use conflicts (both between different marine uses and between users and the environment).

The approach for this project was to develop a model whereby input data (geospatial information describing the physical environment, ecosystems, and fish and wildlife populations) can be integrated into a composite map of ecological value, with weighting factors that incorporate relative intrinsic and ecological values. As part of the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP) project, a framework was developed to model ecological values of marine biological resources. Using synthesized spatial distribution data from various studies performed by University of Rhode Island (URI) researchers, Ecological Value Maps (EVMs) were generated at various levels of detail: on the species level, at the group level, and over all ecological resources. Categories considered for the RI Ocean SAMP application of the EVM framework included the benthic ecosystem, the pelagic ecosystem, fish and large invertebrates, birds, sea turtles, and marine mammals. Bats were also considered in the development of the EVM framework, but were not included in the analysis due to insufficient spatial data.

For the National Oceanographic Partnership Program (NOPP) Project Number: M10PC00097, Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship, funded by the Bureau of Ocean Energy Management (BOEM), the EVM model development performed as part of the RI Ocean SAMP project was expanded to a national level to address cumulative impacts of ORE development. The overall goals of this project are to: 1) Develop methods to design a new conceptual framework and approach for a cumulative environmental impact evaluation of ORE development; 2) Outline an overall SEM that considers both ecological values and socio-economic (human) uses; 3) Integrate various ecological data inputs into an EVM considering multiple levels of organization, i.e., first into ecological components (e.g., individual species) and then ecological categories (e.g., birds, fish, benthic ecosystem); 4) Develop methods to quantify weighting factors for compositing ecological components into an Ecological Value Index (EVI); and 5) Develop methods to quantify weighting factors for modifying the ecological category weights in the EVI related to potential impacts of development in order to generate a Cumulative Impact Model (CIM-Eco), which would become part of the framework for the overall SEM. The CIM-Eco model was tested with an application to the area described in the RI Ocean SAMP, where offshore wind energy development is under consideration.

The results of the CIM-Eco model may be combined with the results of a parallel human use model CIM-HU, which addresses the impacts of development on human uses (ecological services) of the marine environment. The CIM-HU is based on a Human Use Index (HUI) that would include weighting based on relative (human use) service values. The CIM-Eco and CIM-HU indices can then be combined to create a Cumulative Use Evaluation Model (CUEM) (Figure 1). Using these tools, a decision maker could evaluate the impacts of a development, and ideally, the topology of the CUEM composite index would identify areas most suitable for ORE development. The approach is purposefully open, transparent and flexible to facilitate application to a wide variety of sites and environmental conditions.

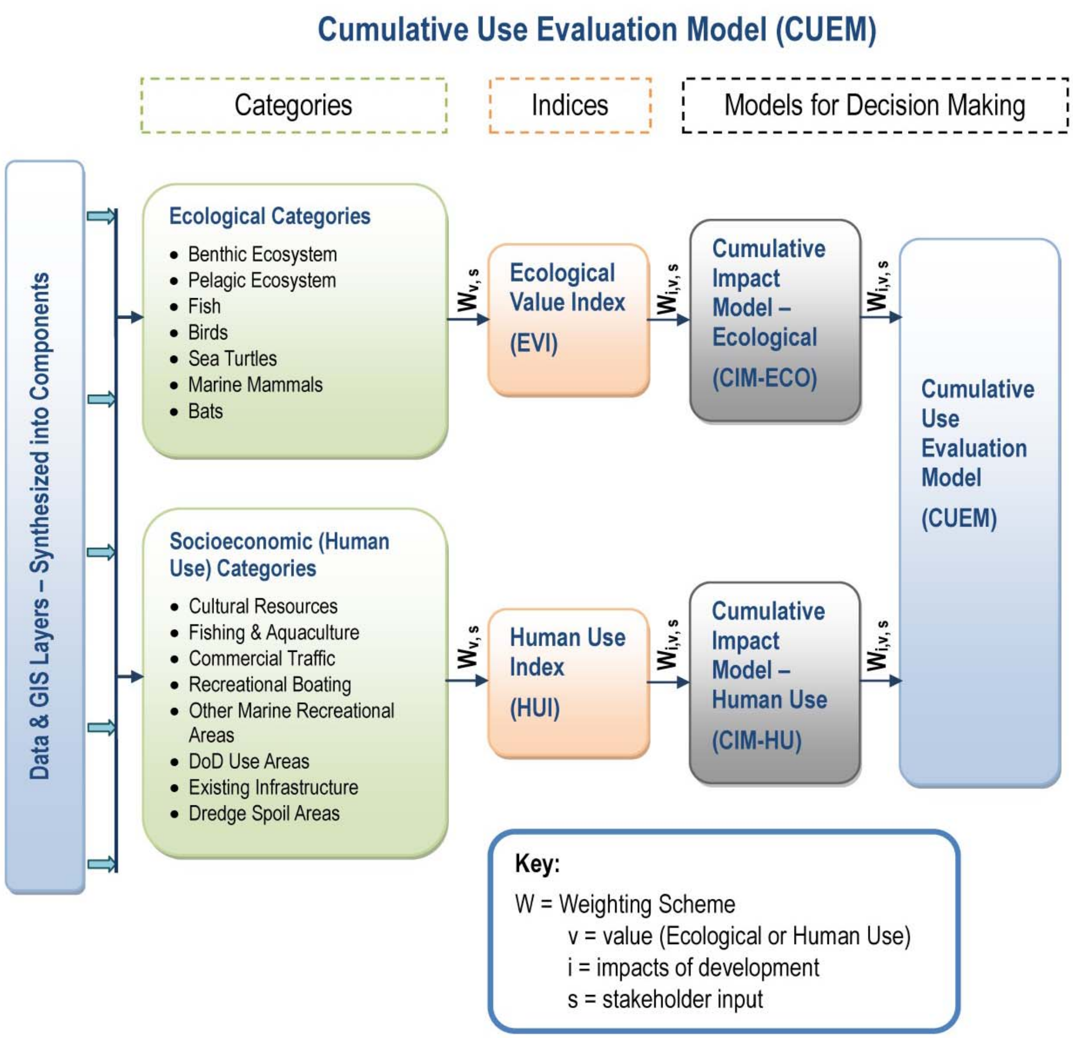


Figure 1. Framework for the Cumulative Use Model (CUEM), including indices of ecological value (EVI, CIM-Eco) and human use (HUI, CIM-HU).

This report describes the expanded framework and an example application of the CIM-Eco model to the RI Ocean SAMP area. Also included with this report is a new software tool, the CIM-Eco Calculator, developed by RPS ASA to allow the user to analyze various configurations for the RI Ocean SAMP area, as well as apply the CIM-Eco model framework to other geographic areas. The CIM-Eco Calculator is discussed in Section 2.2.3 and a detailed user guide is provided as Appendix A.

The CIM-Eco framework is described in Section 2.2, along with example results (Section 2.4) generated using the CIM-Eco Calculator and data from the RI Ocean SAMP. A description of the RI Ocean SAMP data inputs used to generate the example results is provided as Appendix B.

To develop the approach described above, several supporting analyses and/or steps were performed to achieve a robust and comprehensive framework. The first step included a full search and review of the existing pertinent literature (see Appendix C, summarized in Section 2.1). Land- and marine-based biodiversity zoning models, marine protected area and marine spatial planning siting analyses and approaches, and current biological valuation and ecosystem-based management literature were investigated. Several of the approaches and themes reviewed were incorporated into the CIM-Eco framework.

The CIM-HU and CUEM models are described in Sections 3 and 4, respectively. Conclusions and recommendations are provided in Section 5.

2. CUMULATIVE IMPACT MODEL – ECOLOGICAL

The CIM-Eco portion of the Siting Evaluation Model is generated by the application of two intermediate products, category-level EVMs, and a composite EVI. First, ecological data inputs representing various components (e.g., individual species) are integrated into a series of category-level EVMs (e.g., birds) using a variety of weighting factors. The EVMs are then summed into an EVI. Weighting factors quantifying the potential impacts of ORE development are used to modify the ecological category weights in the EVI in order to generate the CIM-Eco index. One of the strengths of this approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented.

The results of the CIM-Eco may be combined with the results of a parallel human use model CIM-HU, described in Section 3, which addresses the impacts of development on human uses (ecological services) of the marine environment.

2.1. BACKGROUND: MEASURES OF ECOLOGICAL VALUE

This section provides a brief summary of the existing marine spatial planning and ecological valuation literature that informed the development of the CIM-Eco model and approach. An expanded literature review is provided as Appendix C to this report.

Assigning value to subareas or zones of the marine environment is not an easy task. Marine environments are intricately complex and typically multifaceted, and provide many services both to natural resources (i.e., fish and wildlife) and to humans. Past valuations have attempted to measure ecological importance, goods and services provided to humans, or both. Methods of valuation in the marine environment have evolved from land-based biodiversity and zoning assessments, natural resource management, marine protected area (MPA) siting analyses, and most recently marine spatial planning efforts. With the onset of marine ecosystem-based management, valuation siting analysis efforts have shifted their focus towards biodiversity and ecology. Under the ecosystem-based management approach, valuation of the marine environment should be related to measures of biological and habitat importance. Because the science of valuation is rooted in both socio-economic and environmental practices, there is cross-over in descriptive terminology making accurate definitions all the more important.

The socio-economic definition of the term "value" refers to the goods and services provided by the marine ecosystem, or the value of an area in terms of importance for human use (Nunes and van den Bergh, 2001; De Groot et al., 2002). This socio-economic definition or inference of the term "value" (which is often tied to a monetary unit) is more traditional and rooted in economic theory. Human uses of biological resources include consumptive uses (e.g., commercial fisheries harvest, recreational fishing), non-consumptive uses (e.g., scuba diving, wildlife viewing, aesthetics, spiritual enrichment), and non-use (e.g., option, bequest, genetic pool, existence) values (Freeman, 1993; Kopp and Smith, 1993; Unsworth and Bishop, 1994; Smith, 1996). Many attempts have been made to measure the value of these services in economic terms, with value being defined as the aggregate "willingness-to-pay" by all individuals for all the services associated with the functioning of the ecosystem (e.g., Freeman, 1993; Smith, 1996). In practice, this approach requires considerable research and site-specific data, relying on proxy markets for ecological services that are not in fact directly traded in the marketplace. If site-specific data are not available, value transfers from other markets or locations are typically made, with a great deal of associated uncertainty. Alternatively, non-market valuation techniques such as Contingent Valuation, which involves questioning samples of people regarding willingness-to-pay for ecological services, are used to estimate monetary values of services. However, these methods are difficult to apply without bias and the results, therefore, are highly variable and uncertain (NOAA, 1992). Thus, while monetary valuation is theoretically possible as a metric for mapping values of ecological resources, in practice the approach requires considerable site-specific research effort, is very subjective (as human perception of value is involved), and is highly uncertain. Thus, we do not attempt monetary valuation as part of this study.

For similar reasons, under the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. § 9601 et seq.), the Clean Water Act (33 U.S.C. § 1251 et seq.), the National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), and the 1990 Oil Pollution Act (33 U.S.C. § 2701 et seq.), scaling mitigation of equivalent value to lost ecological services (resulting from discharges of oil, releases of hazardous substances, physical injury, etc.) has been based on compensatory restoration rather than monetary valuation. The compensation is in the form of equivalent ecological and human services to the injuries, often measured by totaling ecologically-equivalent production of biomass or service-years of resource life (NOAA, 1995). The basis of the compensatory restoration/mitigation approach is a more objective scientific approach: ecological valuation based on biodiversity metrics. In recent marine spatial planning and ecological valuation efforts, the term "value" has been scaled to these biodiversity metrics, and refers to the intrinsic value of marine biodiversity, without reference to anthropogenic use (DFO, 2005; ENCORA/MARBEF, 2006; Derous et al., 2007a,b,c). In this case, the term refers to multiple levels of marine biodiversity, from species to communities to ecosystem-level processes. This biodiversity metric is the basis of the EVI developed herein, as discussed further below.

The most notable and recent concept for marine biological valuation, representing consensus of multiple European researchers, has been developed by Derous et al. (2007a,b,c), where marine biological valuation is defined as the determination of value of the marine environment from a "nature conservation perspective." Their valuation methodology provides an integrated view of "the intrinsic value of marine biodiversity, without reference to anthropogenic use" and purposefully does not include the socio-economic valuation or quantification of goods and services. This methodology entails compilation of biological valuation maps (BVMs) using available marine ecological and biological data where intrinsic value is assessed using biological valuation criteria. BVMs can then be used as baseline data for spatial planning efforts and allow managers and planners to make objective and transparent decisions.

Derous et al. (2007b) applied the biological valuation method to the Belgian region of the North Sea. Biological value was assessed using valuation criteria, a set of assessment questions for each criterion, and appropriate scoring systems. Derous et al. (2007b) make the point that biological valuation is transparent if assessment questions are objective, clear, and centered on the selected valuation criteria. Valuation should not be done solely using expert judgment, as this can lead to subjectivity in the assessment and unrepeatable results. It is critical that any method employing subjective judgments structures these judgments in a manner that enhances replicability (Smith and Theberge, 1987). Detailed assessment questions about "structures and processes of biodiversity" will result in objective valuation, whereas assessment questions straying from this theme may result in scoring from one's own perspective, leading to incomparable results among valuations. Selection and development of assessment questions must occur on a case-by-case basis and should be appropriate for that area. Assessment questions are dependent on data availability and the presence of certain processes/structures, etc.

A workshop jointly sponsored by European Network on Coastal Research (ENCORA) and the Marine Biodiversity and Ecosystem Functioning (MARBEF) network in 2006 in Ghent, Belgium brought together European researchers and managers to discuss the definition of marine biological valuation, and further developed prototype protocols for mapping and determining intrinsic biological value (valuation criteria) as defined by Derous et al. (2007a) (ENCORA-MARBEF, 2006). The biological valuation criteria identified in Derous et al. (2007a) were discussed at length and re-assessed for future case-study frameworks, renaming the general term "marine biological valuation" to "marine biodiversity valuation" or "marine ecological valuation." The 1st order valuation criteria, which measure biodiversity, were refined to "rarity" and a combined "aggregation-fitness consequences" criterion (Derous et al., 2007c):

- Rarity – The degree to which a subzone is characterized by unique, rare, or distinct features (e.g., landscapes, habitats, communities, species, ecological functions, geomorphological characteristics, or hydrological characteristics) for which no alternatives exist.
- Aggregation-fitness consequences – The degree to which a subzone is a site where most individuals of a species are aggregated for some part of the year; or a site which most individuals use for some important function in their life history; or a site where some structural property or ecological process occurs with exceptionally high density; or the degree to which a subzone is a site where the activity(ies) undertaken make a vital contribution to the fitness (i.e., increased survival or reproduction) of the population or species present (DFO, 2005; Derous et al., 2007c).

In Derous et al.'s (2007a) original framework, the 1st order valuation criteria can be modified based on two other factors: naturalness and proportional importance, which are defined as:

- Naturalness – The degree to which an area is pristine and characterized by native species (i.e., absence of perturbation by human activities and absence of introduced or cultured species).
- Proportional importance:

  Global importance – proportion of the global extent of a feature (habitat/seascape) or proportion of the global population of a species occurring in a certain subarea within the study area.

- Regional importance – proportion of the regional (e.g., NE Atlantic region) extent of a feature (habitat/seascape) or proportion of the regional population of a species occurring in a certain subarea within the study area.

- National importance – proportion of the national extent of a feature (habitat/ seascape) or proportion of the national population of a species occurring in a certain subarea within territorial waters.

The ENCORA/MARBEF workshop resulted in naturalness being excluded from the framework altogether, as the natural state of most waters is unknown and it is difficult to define and apply naturalness without reference to human impact. It was decided that naturalness, or measures thereof, should be assessed after the biological valuation process is completed. Also, instead of keeping "proportional importance" as a modifying criterion, it was decided that the valuation should be carried out in two ways: at a local scale and at a broader (eco-regional) scale (Derous et al., 2007c).

Biological valuation methods developed by Derous et al. (2007a) do not give information on potential impacts of any activity, rather they provide a measure of intrinsic biological value. Therefore, evaluation criteria such as "resilience" and "vulnerability," which are based on some measure of impact, human value, or judgment, are not included in their scheme. They argue that these types of criteria should be considered only after the baseline intrinsic value has been established to answer site-specific questions such as suitable placement for development projects or selection of MPAs.

Based on our review of existing literature (see Appendix C), we found the ecological valuation metrics developed by Derous et al. (2007a,b,c) to be the most scientifically-based, transparent approach, with the least bias in application. This approach forms the basis of the EVI model discussed herein. Going a step further than Derous et al.'s (2007a,b,c) approach, we also applied weighting factors to allow the evaluation of cumulative impacts of ORE and other developments (the CIM-Eco model).

2.2. METHODS

Drawing from the biological valuation approach developed by Derous et al. (2007a,b,c), a framework was developed where the ecological values of marine biological resources are modeled. The framework and approach integrate input data (geospatial information describing the geophysical environment, fish and wildlife species distributions, and ecosystems) into a series of category EVMs, incorporating weighting schemes that reflect relative intrinsic ecological value. At the species level, the input data are based on measures of aggregation: density, contribution to fitness, productivity, and rarity or uniqueness of attributes. Different criteria - such as the global, regional, or national importance of local species - can change the relative importance of the input layers to the EVM. These EVMs are then summed to generate an overall composite EVI (Figure 2). Weighting factors quantifying the potential impacts of ORE development are used to modify the ecological category weights in the EVI in order to generate the CIM-Eco index.

The flexible weighting schemes are designed so that managers can integrate stakeholder input and analyze various configurations of the composite EVI. The weighting schemes are described in detail in Section 2.2.1.

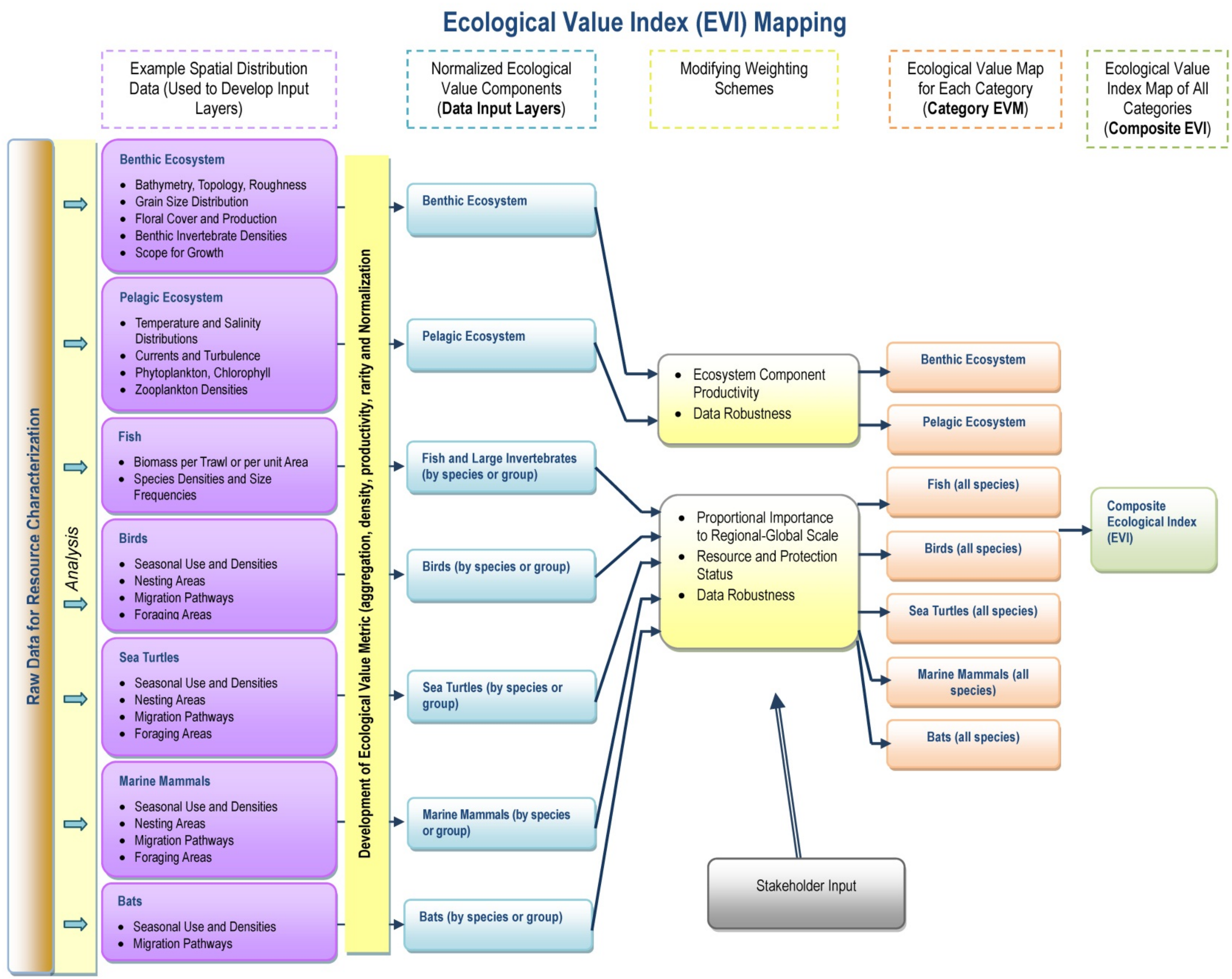


Figure 2. Flow Chart for Development of Ecological Value Maps (EVMs) and the Ecological Value Index (EVI).

2.2.1. Relative Weighting Schemes

The weighting schemes employed in the CIM-Eco framework and CIM-Eco Calculator interface are described below. These weighting schemes are set on a relative scale from 1 (no extra weight) to 10 (highest weight).

2.2.1.1. Component-Level Weighting Schemes

Weighting schemes discussed in this section include "Proportional Importance to Regional-Global Scale," "Resource and Protection Status," "Ecosystem Component Productivity," and "Data Robustness." These weighting schemes are applied at the component level, i.e., that of individual species/resources. The Proportional Importance to Regional-Global Scale and Resource and Protection Status weighting schemes are applied to individual species/groups of birds, marine mammals, sea turtles, and fish/invertebrates. The Ecosystem Component Productivity weighting scheme is applied to the pelagic and benthic environment components. The Data Robustness weighting scheme is applied to all components. Application of these weighting schemes results in category-level EVMs that are then compiled into a composite EVI.

Proportional Importance to Regional-Global Scale

The national, regional, and global distributions of resources may be used to put resource occurrences in the study area into various contexts. If a resource is confined within the study area, it should potentially be handled differently than one that has a global distribution. For example:

- Is the local population of this species a major proportion of the national/regional/global population?
- Is the local population of the species otherwise important to the national/regional/global population? (e.g., does the local subpopulation provide important genetic diversity to the larger population?)

In order to determine the proportional importance of the study area, each biotic resource can be evaluated based on the biogeographic setting classification structure defined by the Coastal and Marine Ecological Classification Standard (CMECS; FGDC, 2012):

- Realm – a very large region across which biota are coherent at higher taxonomic levels. Defining factors include water temperature and historical and broad scale isolation.
- Province – large areas where distinct biota have some cohesion over evolutionary time due to distinctive abiotic features. Examples of those features include nutrient supply and salinity, currents and upwellings, semi-enclosed seas, and shelf systems.
- Ecoregion – areas of relatively homogenous species composition, clearly distinct from adjacent systems.

For example, the RI Ocean SAMP study area is located in the Temperate Northern Atlantic Realm, the Cold Temperate Northwest Atlantic Province and the Virginian Ecoregion, as defined by Spalding et al. (2007). The Virginian Ecoregion stretches from Pamlico Sound, North Carolina to Cape Cod, Massachusetts. The Cold Temperate Northwest Atlantic Province encompasses the water from Pamlico Sound to Newfoundland, Canada. The Temperate Northern Atlantic Realm includes the waters of the northern Gulf of Mexico, the entire east coast of the United States, the Atlantic coasts of the northern and western Europe and northwestern Africa, and all the inland European seas.

This weighting scheme, scaled from 1 = lowest importance to 10 = highest importance at the global scale, is mainly used to generate category EVMs, but may also be used to depict importance of local components (e.g., certain benthic habitats) over more globally distributed components (e.g., sea turtles) in a composite EVI. Below is the scheme utilized:

- 10 – Distribution endemic to study area
- 8 – Distribution endemic to the study area's Ecoregion
- 6 – Distribution covers only a subset of the study area's Province
- 4 – Distribution covers only a subset of the study area's Realm
- 2 – Distribution throughout the study area's Realm
- 1 – Global distribution

Resource and Protection Status

Some species have been designated by governments and international organizations as at higher risk for extinction than others. These designations are usually a result of declining population numbers. However, just because a population on the whole is declining in numbers does not necessarily mean that all subsets of the population face the same problem. Likewise, a population on the whole could be stable while a subpopulation is currently declining. Because of this distinction several questions need to be considered when evaluating how to weight population status, including:

- Is the population (or population segment) listed as a species of special concern, threatened, endangered, or not listed?
- How prevalent is the population in the study area?

A weighting scale that reflects protection and population status, as applied here, is:

- 10 – Listed as endangered at the federal level
- 9 – Listed as endangered at the state level
- 8 – Listed as threatened at the federal level
- 7 – Listed as threatened at the state level

- 6 – Listed as a species of concern at the federal level, a candidate species for listing, or afforded special protection under regulations other than the Endangered Species Act (e.g., Marine Mammal Protection Act, Migratory Bird Treaty Act)
- 5 – Listed as a species of concern at the state level or a candidate species for listing
- 4 - Not listed, but at low population size relative to historical levels
- 3 - Not listed, but decreased or decreasing population size
- 2 - Not listed, at approximately historical population size
- 1 - Not listed, highly abundant compared to historical levels.

In addition to weighting the entire data layer according to protection status, portions of the gridded data layer could be weighted differently to highlight the importance of certain protected areas, such as MPAs or areas designated as critical habitat. In this way, both spatially-discriminated protection (MPAs) and species-specific protection could be incorporated into the weighting scheme and EVI. This type of weighting is not included in the present application.

Ecosystem Component Productivity

For data layers defined by productivity (i.e., the benthic and pelagic ecosystem components), the previous two weighting schemes are not applicable. Instead, productivity in the region of interest is evaluated based on two criteria: what level of productivity results in the highest ecological value, and what ecological value should be applied at maximum productivity. Defining these two points will frame the productivity data appropriately into the ecosystem and establish the shape of this weighting function, which can then be applied to the data.

When evaluating productivity the following questions establish the weighting function:

1. What productivity level (p, on the normalized 0-1 scale of the input data) corresponds to the highest ecological value?
2. What weighting value (w_p, 1-10) should be applied at that highest ecological value?
3. What weighting value (w_{max}, 1-10) should be applied at maximum productivity (PI=1)?

This weighting scheme addresses a central question in the field of ecology: what is the relationship between biodiversity (referred to here as "ecological value") and productivity? A recent review (Graham and Duda, 2011) of functional relationships with species richness describes a number of complexities. The most commonly observed functions of diversity and productivity are "humpback" shaped (e.g., Figure 3a), but may also be monotonically increasing (e.g., Figure 3b), monotonically decreasing, U-shaped or J-shaped. Based on the answers to the questions listed above, the user can apply a wide variety of shapes for this weighting function; some example weighting functions are shown in Figure 3. A humpback-shaped relationship between biodiversity and productivity describes a situation where species richness increases with increasing productivity and then decreases as productivity increases further (Graham and Duda, 2011). This function is likely the most relevant to the widest range of users, and therefore it is the recommended default function for benthic and pelagic input data layers. We provide a two-segmented linear model for the humpback function here and in the CIM-Eco Calculator, for simplicity. If the benthic and/or pelagic ecosystem components are instead defined by an index of environmental or habitat quality, for example, a continuously-increasing linear model should be adopted where the highest index values relate to the highest ecological value.

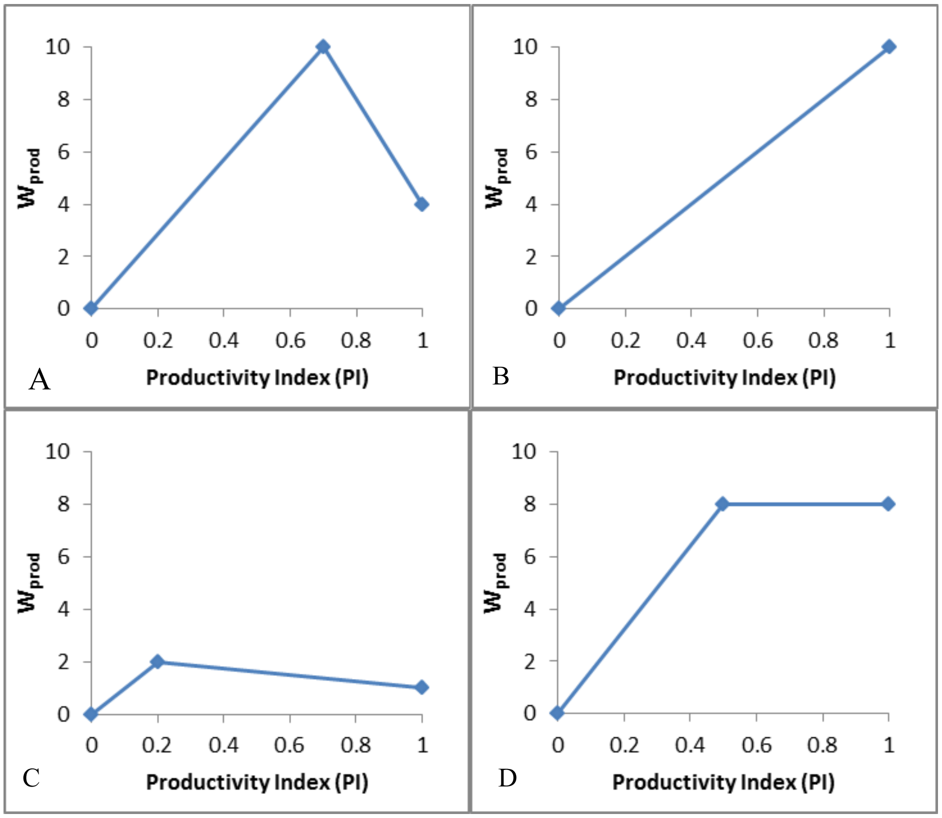


Figure 3. Example Ecosystem Component Productivity weighting functions (W_{prod}) resulting from input values of: a) p=0.7, w_p=10, w_{max}=4; b) p=1, w_p=10, w_{max}=1; and c) p=0.2, w_p=2, w_{max}=1; and d) p=0.5, w_p=8, w_{max}=8.

As an example, chlorophyll *a* concentration could be used as the metric of primary production to represent the pelagic ecosystem. In an environment such as the Louisiana shelf in the northern Gulf of Mexico, increased production is beneficial up to a certain point, and then becomes detrimental as production continues to increase, leading to overgrowth and the potential creation of hypoxic zones. In this case, the highest ecological value may occur at a chlorophyll *a* concentration level of say 70% of the maximum, thus the value given for the first question would be 0.7. The second question refers to the ecological value weighting (1-10) that should be applied to this level of production. Nominally, the value given for this level of production would be low, say 2, since for ORE siting pelagic production is less of a concern than other resources, such as protected species. However, other weightings could be applied if desired (e.g., if the user wanted to weight benthic production higher than pelagic production, they could apply a maximum weighting value of say 3 to the benthic production layer and a maximum weighting value of 2 to the pelagic layer). The third question allows the detrimental component of more productivity to be evaluated in that the maximum level of production in the input data (=1) may be less ecologically beneficial than a lower production level. For the northern Gulf of Mexico shelf example, a lower weight would be applied to this level of production. In another, less-stressed environment where nutrient loadings are lower than those causing hypoxia, the maximum production level may not cause ecosystem stresses and therefore the answer to question one is 1, question two might be valued as a 2, and question three defaults to the value answered for question two.

Data Robustness

The evaluation of resource values in an EVI is only as reliable as the input data; and different resources require varying degrees of effort for data collection. Thus, uncertainty associated with collected data and model input layers needs to be evaluated. Data sets with more spatial coverage/accuracy should be distinguished from data sets requiring a lot of interpolation to generate a complete input layer. Questions that define data robustness include:

- What is the sampling resolution (spatially and temporally)?
- How many years of data are included?
- How frequently were the data collected?
- What methods were used to create a continuous surface?

There are no defined values for this weighting scheme, as this is a relative relationship between the data sources used. As such, the user should evaluate the data sources as a whole and decide how these questions differ between them. Concepts to consider include data layers with higher resolution in space and time may be given relatively higher weights, whereas sparse data sets needing interpolation are weighted lower. Or, having multiple years of data collections would warrant a higher weighting than data for a single year or season. For the application of this framework to the RI Ocean SAMP data, this weighting scheme was set to a default of 1 (i.e, no additional weight) for all layers.

2.2.1.2 Category-Level Weighting Schemes

This weighting scheme is applied at the category level (i.e., birds, marine mammals, sea turtles, fish and large invertebrates, benthic environment, and pelagic environment) to overlay the relative potential impact of ORE development onto the composite EVI map, generating the CIM-Eco map.

Relative Potential Impact of Development

The relative potential impact of development is generally project- and site-specific. That is, impact type and degree of effects are dependent on location (physical and biological conditions), the energy project type (e.g., wind, wave, tidal current), the scale of the project, the methodologies employed, and the project phase (e.g., construction, operation, decommissioning).

The Year 1 deliverable entitled "Task 1.2 Report on Monitoring the Potential Effects of Offshore Renewable Energy," focused on understanding the potential effects associated with

ORE development. In this report, potential effects on benthic habitat, fish, fisheries, marine mammals, sea turtles, and bird species were identified and categorized according to the level of impact and the level of certainty at each of three scales of development (i.e., demonstration-scale, commercial-scale, and multiple large-scale facilities in a region) and for several ORE technology types (i.e., various wind, wave, and tidal energy technologies) to generate the Offshore Renewable Energy Effect Matrix.

In the matrix, the magnitudes of potential effects (either positive or negative) are represented by color, with red representing effects that are considered to generate the greatest change or impact to a resource, yellow representing effects that are expected to generate a moderate amount of change or impact, and green representing effects that are expected to generate little to no change or impact. Blank cells represent no effect. Because the matrix does not distinguish between negative impacts or positive benefits, some of the effects categorized as major, moderate, or minor may be viewed as beneficial. The matrix also incorporates a measure of level of certainty, where the most transparent shading represents potential effects in which there is very little certainty, whereas the darkest or most opaque colors represent potential effects in which there is a higher degree of certainty regarding the level of impact or effect. As an example, Figure 4 shows the Offshore Renewable Energy Effect Matrix for marine mammals and sea turtles for a single commercial scale ORE facility.

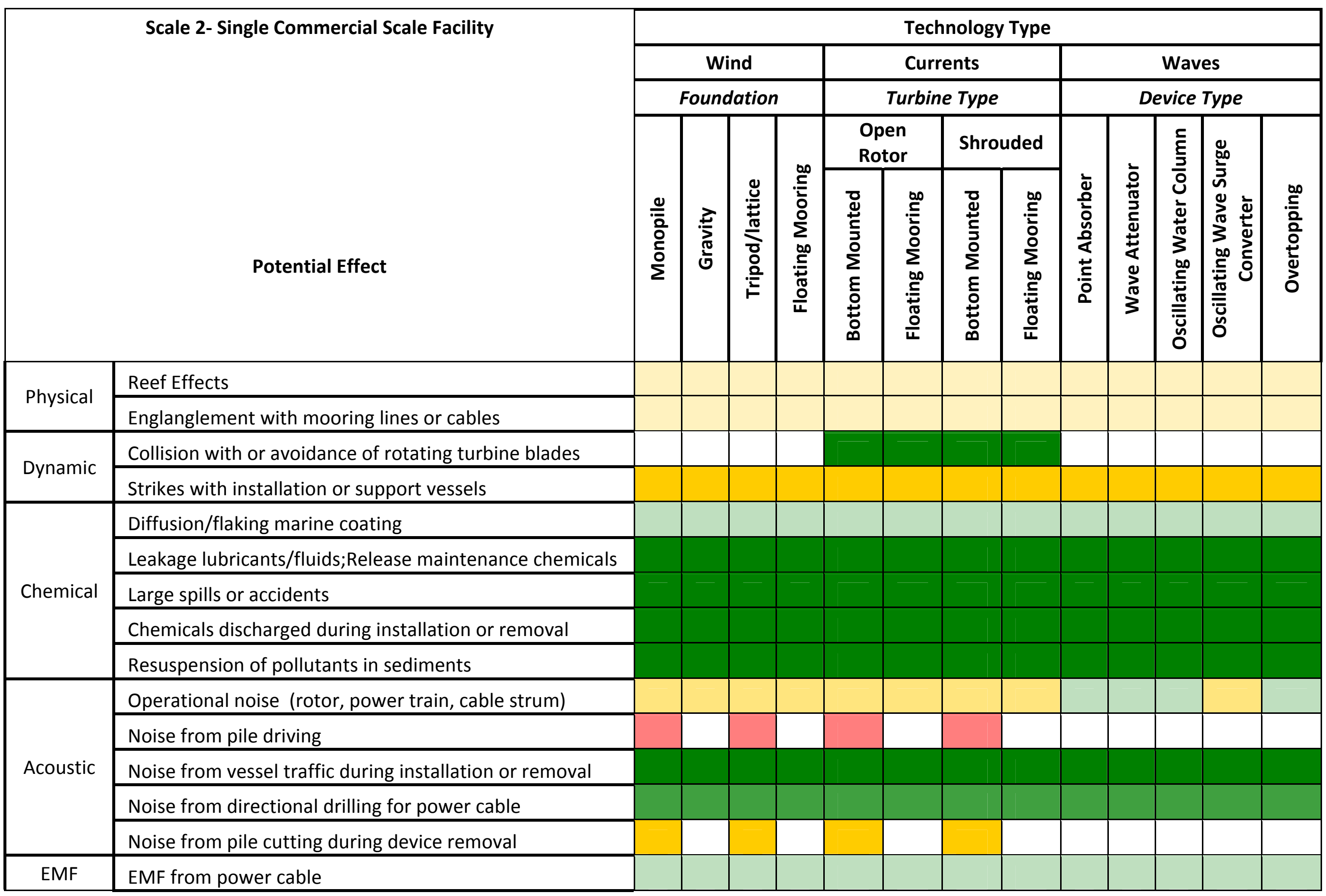


Figure 4. Offshore Renewable Energy Effect Matrix for marine mammals and sea turtles for a single commercial scale facility.

As part of the Task 1.5 Final Report, the information from the Offshore Renewable Energy Effect Matrix is used to inform an "Effects Decision Tree" that guides the user in determining which ecosystem components may experience moderate and/or major effects for various ORE development types. This information is found entirely within the Offshore Renewable Energy Effect Matrix, but is presented in a more accessible format as a decision tree. In this tree, the user answers a series of questions about the development project (e.g., energy type, foundation type, development scale) and is guided through the decision tree to six main Effect Scenarios that detail the ecosystem components potentially affected, the number of major and/or moderate effects, and whether those effects are positive or negative in nature. The decision tree Effect Scenarios are "pooled" from the Matrix (i.e., they apply to four or more development scenarios). If the user wants to address only one specific ORE development type, the information in the Matrix can be used directly to determine the potential effects.

To generate CIM-Eco maps, the Effect Scenario determined by the Effects Decision Tree is used as a guide in assigning an adverse impact weighting to each resource category for a particular type of ORE technology and project scale. It is important to note that the magnitude of the effect in the Offshore Renewable Energy Effect Matrix and Decision Tree refers to both beneficial and adverse effects, whereas the intention of the impact weighting in the CIM-Eco model is to evaluate adverse effects only. Therefore, when averaging the matrix results to determine the impact weighting to apply to a category, beneficial effects should be excluded.

For example, if the ORE development is a commercial-scale wind turbine facility with lattice foundations, the Effect Scenario is determined to be "E2A." The pie chart associated with Effect Scenario E2A (Figure 5) summarizes the magnitude of positive and negative effects anticipated for each resource category for this type of development. This pie chart also shows the proportion of effects for each category that are positive (i.e., beneficial), minor, moderate, and major (adverse).

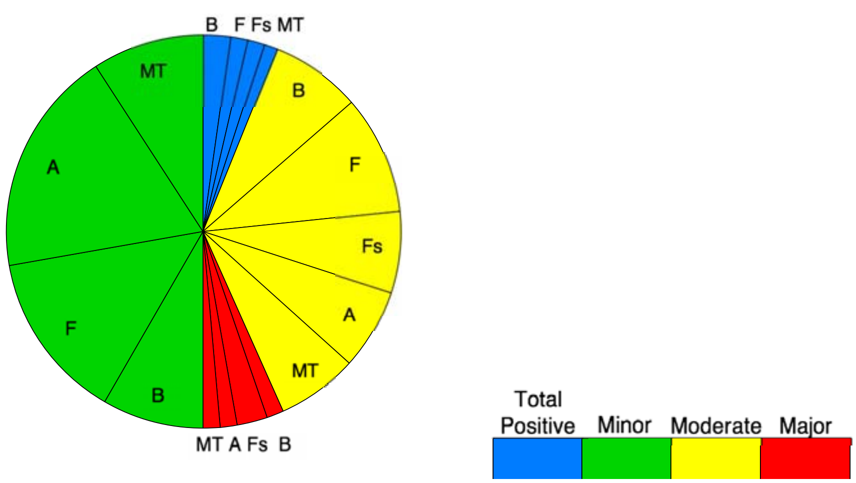


Figure 5. Summary pie chart for Effect Scenario E2A, adapted from the Task 1.5 Final Report. A = Avian species; B = Benthos; F = Fish; Fs = Fisheries; and MT = Marine mammals and sea turtles.

Using this information as a guide, and excluding beneficial effects, the user can determine an appropriate impact weighting to apply for each resource category. For example, based on the effects scenario for a single commercial-scale wind facility with lattice foundations (scenario E2A, shown above), marine mammals and sea turtles may be subject to several minor adverse effects, several adverse moderate effects, and very few major effects. If all of these effects are assumed to be of relatively equal likelihood, the user would assign an impact weighting of moderate or moderate-major. Conversely, fish are shown to potentially be subject to several minor adverse impacts, many moderate adverse impacts, and no major adverse impacts. Thus, this category might be weighted as moderate or minor-moderate.

The approach described in the previous paragraph assumes that all potential impacts have the same likelihood; in reality, some effects, while potentially having a large adverse impact, may be extremely unlikely. This weighting scheme is very flexible and the user could take this and other information (e.g., such as proposed mitigation) into account in applying the weighting scheme. Site-specific issues may warrant modification of the relative effects findings that were used to develop the Offshore Renewable Energy Effect Matrix. Also, CIM-Eco maps can be generated considering only some of the Matrix, for example by considering a single potential effect (e.g., noise from pile driving) or a group of effects (e.g., physical, chemical, acoustic, electromagnetic fields [EMF]), or by giving the factors varying weights in compositing the overall weight. Other weighting schemes could also be developed and used in the framework of the CIM-Eco model.

The values associated with this weighting scheme in the model are as follows:

- 10 – Major adverse impact
- 8 – Moderate-major adverse impact
- 6 – Moderate adverse impact
- 4 – Minor-moderate adverse impact
- 2 – Minor adverse impact
- 1 – No adverse impact

2.2.2. CIM-Eco Model Calculation Methods

The first step in the CIM-Eco approach is to develop geospatial data or maps for each ecological resource to be included, gridding the data over the area of interest. An input layer is developed for each resource (e.g., a species or group) using spatial distribution data or other appropriate metrics.

In the second step, the component data are converted into an ecological valuation metric. Most of the ecological valuation metrics are based on standard biological metrics, such as density (number of individuals or biomass per unit area), productivity (amount of production per unit time per unit area), or resource classifications (e.g., benthic ecosystem components transformed into relative values by evaluating how frequently each classification occurs within the study area).

In order to compare across species/resources, each input layer is normalized to a 0 to 1 scale. This simplifies the relationship between the input layers by removing the order of magnitude differences that can arise between raw values. In the examples provided herein, this procedure is completed in ArcGIS 9.3, where the annual maximum raw value (e.g., abundance, sightings per unit effort, etc.) for each component was used to normalize each of the seasonal data layers. Annual average layers were then calculated by summing the normalized seasonal layers and dividing by the total seasons sampled.

When combining multiple component layers, the simplest approach is to sum all the values and generate a total for each location (grid cell), which creates a map assuming all contributing data layers are of equal weight. However, many different concerns (e.g., the importance of species, robustness of data, potential for impact by a project) can vary the relative importance of one layer versus another. Therefore, in this model framework, individual normalized component layers are combined using relative weighting schemes to develop category EVMs (e.g., birds). Then, the category EVMs are compiled to derive a composite EVI (see Figure 2). A weighting scheme reflecting the relative potential impact of ORE development can then be applied to the composite EVI to generate the CIM-Eco index. The weighting schemes used in this analysis are described in detail in Section 2.2.1.

The weighting schemes utilized for this study can be represented as the following variables:

$$Regional/Global\ Importance = W_{rg}$$
$$Protection\ Staus = W_{ps}$$
$$Ecosystem\ Component\ Productivity = W_{prod}$$
$$Data\ Robustness = W_{dr}$$
$$Potential\ Impact = W_{imp}$$

To develop category EVMs for birds, marine mammals, turtles, and fish and large invertebrates, the normalized input data rasters (i.e., the gridded data of value measures were divided by the maximum value in the grid [or the seasonal maximum] and so normalized to a common scale) were multiplied by the regional/global importance and protection status weighting schemes, as well as a weighting scheme corresponding to data robustness. The output is then divided by 3, representing the three weighting schemes that were applied. In order to prevent categories with more input data rasters from being disproportionately represented in the results, the resulting output rasters are then summed and divided by n, where n is the number of input data rasters (e.g., the number of species layers) in the category. This procedure is described by the following equation, where x is the normalized input data:

$$For\ birds, mammals, turtles, and\ fish: Category\ EVMs = \frac{\sum_i \left(\frac{x_i\, W_{rg_i} W_{ps_i} W_{dr_i}}{3} \right)}{n}$$

To develop category EVMs for the benthic and pelagic environment, a weighting function is applied such that the value of W_{prod} varies with the value of the normalized input data raster (which is based on a metric of productivity, referred to here as the productivity index, or PI).

This function is determined by three user-defined inputs (discussed in more detail in Section 2.2.1.1) that define a two-segment linear model that represents the relationship between productivity and biodiversity (i.e., ecological value):

- p, the productivity index (PI) level (on the normalized 0-1 scale of the input data) corresponding to the highest ecological value;
- w_p, the weighting value applied at that highest ecological value (p); and
- w_{max}, the weighting value applied when the productivity index equals 1.

Using these variables, the value of W_{prod} at a given PI value is determined according to the following equations:

$$when\ PI \leq p,\ W_{prod} = \frac{w_p}{p} * PI$$

$$when\ PI > p,\ W_{prod} = (PI - p)\left(\frac{w_{max} - w_p}{1 - p}\right) + w_p$$

Refer to Figure 3 in Section 2.2.1.1 for some example W_{prod} functions resulting from various values of p, w_p, and w_{max}.

The benthic and pelagic category EVMs are calculated by multiplying the normalized input data by the W_{prod} weighting (determined by the functions described above), as well as a weighting scheme corresponding to data robustness. The output is divided by 2, representing the two weighting schemes that were applied. The resulting output rasters are then summed and divided by n, where n is the number of input data rasters in the category. This procedure is described by the following equation, where PI is the normalized productivity index input data:

$$For\ benthic\ and\ pelagic\ ecosystem{:}\ Category\ EVMs = \frac{\sum_i \left(\frac{PI_i\, W_{prod_i} W_{dr_i}}{2}\right)}{n}$$

The composite EVI is produced by summing the all of the category EVMs:

$$Composite\ EVI = \sum_i Category\ EVMs_i$$

Weighting factors quantifying the potential impacts of ORE development are used to modify the ecological category weights in the EVI in order to generate a Cumulative Impact Model (CIM-Eco):

$$CIM\text{-}Eco = \sum_i Category\ EVMs_i * W_{imp_i}$$

2.2.3. CIM-Eco Calculator

Also included with this report is a new software tool, the CIM-Eco Calculator, developed by RPS ASA to allow the user to easily carry out the calculations of the CIM-Eco framework as described in this report. The Calculator is pre-loaded with data for the RI Ocean SAMP area (described in Appendix B), but the tool can be applied to any geographic area. It currently includes categories for fish/invertebrates, birds, marine mammals, sea turtles, pelagic ecosystem, and benthic ecosystem. A category for bats in also included, but no data are available at this time for mapping bat distributions in the RI Ocean SAMP area.

The Calculator is a simple tool that allows the user (e.g., developers, regulators) to manipulate the weighting schemes and perform alternative weightings to examine cumulative impacts. Using the CIM-Eco Calculator, all user groups would be able to explore the data and implications at all levels, from input data layers to category EVM, composite EVI, and CIM-Eco maps. These maps may be printed, saved as images, or imported into a GIS system for further analysis and display.

In the future, this tool could be expanded to incorporate the CIM-HU and overall SEM frameworks. It could also be developed as a web-based application, an ArcGIS extension, or another software platform, and made widely available to allow all stakeholder groups to access the data collected and determine how their perception of each resource layer affects the final cumulative impact assessment.

A detailed user guide for the CIM-Eco Calculator is provided as Appendix A.

2.3. Input Data

The following sections discuss the important factors to consider when compiling data for an ecological valuation exercise (Section 2.3.1), as well as potential input data sources (Section 2.3.2).

2.3.1. Data Considerations

Based on our experience in developing the EVM/EVI approach for the RI Ocean SAMP, as well as reviewing other marine spatial planning approaches, there are several challenges in applying ecological valuation as a useable tool for siting efforts. The most important factors influencing the results of the model are: (1) defining the appropriate scale for the valuation effort; (2) a lack of standardized input data; and (3) patchy or inconsistent data availability/ coverage necessitating application of interpolation models or spreading algorithms with uncertain underlying assumptions. These challenges are discussed in more detail below.

2.3.1.1. Issues of Scale

Determining the appropriate scale on which to analyze input data sets is an important element in ecological valuation efforts. The scale heavily influences the results, and therefore inappropriate scales can lead to skewed interpretation and poor decision making. The scale of analysis must be appropriate for the geographic scale of, and processes affecting, the resource in question. For instance, a non-migratory demersal fish species could most likely be assessed appropriately at a local scale, while some migratory species (e.g., large whales) should be assessed at a regional or global scale. Assessing a migratory species with a large geographic range at a local scale may lead to overestimation of the importance of the local area to that species. As an example of this issue, North Atlantic right whales are known to pass through the RI Ocean SAMP area, but their most important habitat areas in the region occur farther north. In our EVM modeling approach for the RI Ocean SAMP project, the North Atlantic right whale data set was normalized only within the SAMP area, rather than within the full geographic extent of the data set. As a result, areas within the RI Ocean SAMP boundaries with known occurrences of North Atlantic right whales were modeled as having higher ecological value than areas where the whales are less likely to occur, even though the SAMP area may be of little importance to the species overall.

The component of regional-global importance is separately addressed in the weighting schemes, which allows the user to rate the importance of the population within the study area to the importance of the population at regional and global scales (Section 2.2.1.1). However, the issue of determining the appropriate scale on which to analyze input data sets is an important matter that warrants special consideration in future ecological valuation efforts.

2.3.1.2. Standardized Data and Spreading Methodologies

Attaining comprehensive data with ample spatial coverage for ecological valuations can be difficult. Marine spatial planning efforts generally require ecological valuation of broad scale coastal zones, but in many cases, ecological data are typically highly variable, patchy, collected for another purpose, and/or focused on a particular area of concern. Data inputs are typically pulled from a variety of sources, and therefore include multiple studies, each with varying scopes, methodologies, and objectives. As a result, it can be challenging to standardize these data sets so that they can be combined in a meaningful way. Furthermore, data may simply not exist for particular ecosystem components, or may not have adequate spatial coverage. The sampling coverage needed to truly represent broad-scale study areas is often unavailable and costly or infeasible to obtain. This is particularly a problem for highly migratory species, which generally operate on broad spatial scales.

Part of this difficulty with standardized input layers can be addressed by the use of a common ecological language. The NOPP project has adopted NOAA's Coastal and Marine Ecological Classification Standard (CMECS) in order to standardize all relevant data layers. Currently, CMECS addresses only the benthic environment (CMECS Geoform, Substrate, and Biotic Components) and the pelagic environment (CMECS Water Column Component). The layers used to represent benthic and pelagic ecosystem components in this analysis (i.e., Scope for Growth index and the chlorophyll *a* concentration) can each be related to relevant CMECS components. If similar efforts are made when applying the CIM-Eco framework in other regions, data could be easily combined to enable very broad-scale analyses or even regional comparisons.

Modeling data layers based on spatial interpolations between points, or extrapolating a surface as a function of a variable with ample spatial coverage has been used as one way to address the data gap problem (Degraer et al., 2008; EOEEA, 2009; Greene et al., 2010). A variety of multivariate analysis methods have been widely applied in ecological studies to spread data and identify and describe patterns. The appropriateness of each method is dependent on several factors including scale (e.g., regional vs. local), the specific objectives of the effort, and most importantly the type of input data.

All statistical analyses operate under various sets of assumptions. Not all data lend themselves to or can meet the specifics of these assumptions. Ecological data often fall into this category. Having a full understanding of each method's underlying operating assumptions and the limitations of the dataset(s) at hand is paramount to meaningful interpretation and use. Often, many of the assumptions associated with statistical analyses are violated, therefore compromising the overall use and interpretation of the results. Scientists and managers must be careful when applying these methods.

When conducting an analysis, our recommendation is to first investigate the limitations of the input data and let the results of that investigation dictate which analyses can be performed. For example, some important questions to ask while investigating input data include: "are the data distributed normally" and "are datasets independent of each other"? These questions will dictate whether parametric approaches are possible, or if Bayesian methods must be employed.

In ORE siting efforts, input data would most likely consist of a collage of data types collected under various circumstances, and in many cases for completely different objectives. Compiling and amalgamating disparate data sets that haven't been collected specifically for geospatial spreading and are not standardized can lessen statistical utility.

For the RI Ocean SAMP, in most cases, continuous topologies were generated by the data providers using a variety of methods, e.g., Kriging (marine mammals, turtles), predictive habitat model based on depth and distance from shore (birds). These inputs are described in detail in Appendix B. From the RI Ocean SAMP exercise, it became apparent that the method used to create a continuous topology can heavily influence the result and create unreliable information and biases, as illustrated in the following example.

For the bird data inputs for the RI Ocean SAMP (Paton et al., 2010), ship-based survey data were used to create surface density models of species common to the area. These surface density models related survey observations with depth and distance to land to predict densities across sampled and un-sampled areas. A grid made up of 2 km by 2 km cells was overlaid over the study area and populated with predicted abundance for each cell (see Figure 6 for an example abundance distribution map). Because the abundance maps are based on a predictive model based on behavior (rather than a spreading model such as Kriging) and patchy observational data, some artifacts of the model are apparent in the maps, namely the light and dark "contours" of abundance at varying distances from shore that result from the distance-from-land-based model. In contrast, a model generated from Ordinary Prediction Kriging shows very different results (Figure 7).

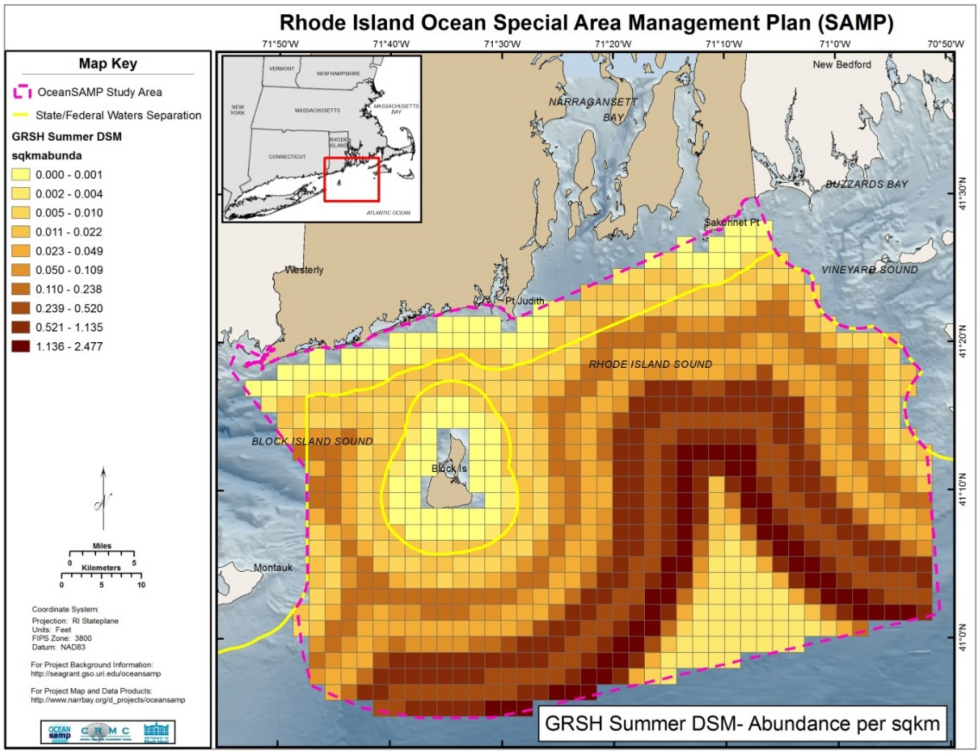


Figure 6. Example abundance distribution map generated by a model of depth and distance from shore (predicted summer greater shearwater abundance per square kilometer).

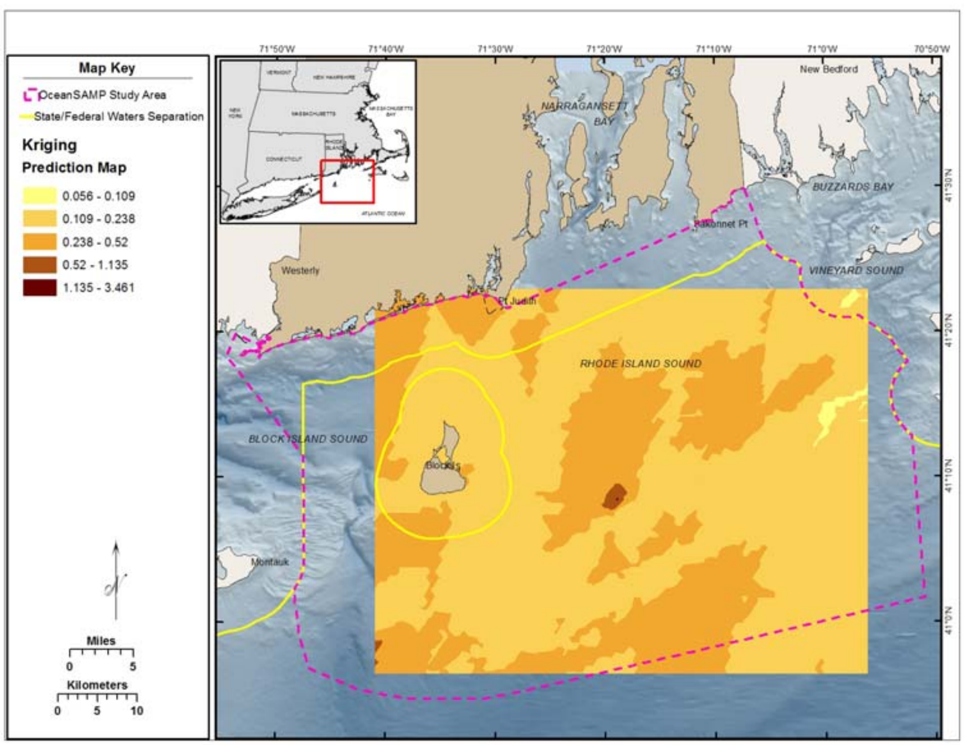


Figure 7. Example abundance distribution map generated by Ordinary Prediction Kriging (predicted summer shearwater abundance per square kilometer, log-transformed).

In view of the reality that data coverage and quality will vary by region and resource, and will rarely be sufficiently complete for spatial interpolation methods to provide reliable surfaces in all locations, we recommend that a hierarchy of approaches be developed for generating topologies, dependent on the nature, comprehensiveness, and uncertainties of the available data. The approaches may include various spatial statistical techniques (e.g., Kriging, Inverse-Distance Weighted Interpolation), empirical models, and behavioral models, depending on data availability and quality.

2.3.2. Potential Input Data Sources

Potential input data sources will vary widely by study location and ecological category. Once decided upon, all data sources should be investigated fully to understand the original source of the data, the limitations of the data, and the appropriate interpolation options. If source data are available they will likely fall into one of two broad categories: (1) resource-specific abundance data or (2) modeled data. These two types of inputs are discussed in Sections 2.3.2.1 and 2.3.2.2, respectively. For categories that do not have abundance data, or for which appropriate abundance data cannot be assimilated, data gaps could be filled by additional data collection (e.g., funded by the BOEM Environmental Studies Branch) or by the completion of a wildlife movement model analysis (Section 2.3.2.2). Potential input data sources are discussed in the following sections. Detailed input data specifications for the CIM-Eco Calculator can be found in Appendix A.

2.3.2.1. Abundance Data and Density Models

As discussed in Section 2.3.1.2, abundance data, which often originate as information collected at discrete points in space and time, can be transformed to generate a smooth surface using a variety of statistical techniques including Kriging and interpolation, or by using other correlative data such as productivity or habitat surfaces. If the products of statistical and empirical models are available, the data user must evaluate their application to ensure that assumptions meet the criteria of their study. If only raw point information is available, the user must decide which type of data spreading meets the needs and assumptions of their study (see example in Section 2.3.1.2). Many organizations have been involved in ingesting and spreading data for a variety of purposes. Some of the larger data sources are described below. If abundance data are not available for the category of interest, data can be collected through field study efforts. For suggestions regarding the collection of data for this purpose, refer to the monitoring protocols discussed in the Task 1.5 Final Report.

The BOEM/NOAA Multipurpose Marine Cadastre (http://www.marinecadastre.gov) has marine mammal and sea turtle density models available for several species, including North Atlantic right, humpback, sei, fin, minke, and sperm whales; bottlenose dolphin; and leatherback, Kemp's ridley, and loggerhead turtles. These layers are smoothed surfaces based on abundance data. Similar datasets for available resources will be added to the Marine Cadastre in the future.

The Nature Conservancy's Marine Ecoregional Assessments are another source of abundance data that have been extrapolated over a surface. This assessment, currently completed for the northwest Atlantic and in process for the North Pacific coast, discusses the data sources and statistical models for all the input data including marine fish, large pelagic fish, marine mammals and sea turtles, shorebirds and seabirds, and ocean processes (http://www.nature.org/ourinitiatives/regions/northamerica/areas/easternusmarine/explore/index.htm; http://maps.tnc.org/NAMERA/).

Special Considerations for Benthic and Pelagic Ecosystem Components

For categories where traditional abundance data do not apply or are not available at broad scales, such as benthic and pelagic ecosystem components, alternative data sources can be sought that better describe the complexities of these systems. The appropriate index to use will vary by study location, as different regions have different variables that better correlate or predict a productive ecosystem. In most cases a proxy data source is used; for example, in the RI Ocean SAMP chlorophyll *a* concentrations were used as a proxy for pelagic productivity. For pelagic processes, other metrics to consider might include an index of upwelling or water column stability. These data are often fairly easy to integrate as they are based on remotely-sensed satellite-derived data and cover the entire region of interest.

Because observations of the seabed are fragmentary (spatially and temporally), the development of continuous seabed characterization maps is very difficult. For ecological valuation maps, a product containing benthic biological information is desirable, whether that is a map of biodiversity, community type, productivity, or some other metric. Because broad-scale physical data (e.g., bathymetry, substrate type, tidal velocity, wave height) are generally more available than broad-scale benthic biology data, the most promising method for creating benthic biological maps is to establish physical-biological linkages and model the biology as a function of physical conditions. These linkages should be derived from each study area independently, as different physical factors are relevant for different ecosystem types (e.g., temperate versus tropical). For small- to meso-scale studies, Brown et al. (2011) reviewed the accepted methodologies for creating benthic "habitat" maps. They defined three broad categories including abiotic surrogacy, supervised classification, and unsupervised classification, which all rely on acoustic (side-scan sonar and/or multibeam) data covering the study area. In very broad-scale studies, where even full-coverage acoustic data are not available, models such as the habitat template of Kostylev and Hannah (2007) are most appropriate. The habitat template consists of a metric of energy available for biological growth and reproduction (Scope for Growth) and a metric of natural physical energy on the seafloor (Disturbance). Either or both of these metrics may be useful in creating benthic environment valuation layers. Using data collected during the RI Ocean SAMP process, Shumchenia et al. (unpublished data) have developed a habitat template, and have encouraged the use of the Scope for Growth layer in the application of the CIM-Eco framework to the RI Ocean SAMP area. For the example results generated for this project (Section 2.4), the benthic ecosystem component was represented by Shumchenia et al.'s Scope for Growth index that combines physical and biological components of the water column and near bottom conditions to describe the potential for production in the benthos (see Appendix B for more detail on this data layer).

As mentioned above, the best metric for a study area will depend on many unique variables and thus careful consideration is required to determine the appropriate layer for each category.

2.3.2.2. Movement Modeled Data

For species where abundance data or density models are not available, modeled movement information may be the best source within the scope of a siting project. For highly migratory species, wildlife movement models may be the most realistic approach for generating reasonably accurate topologies. Considerable information is available on general migratory pathways, the timing of migrations, temporal distributions of sightings, behavior of animals while migrating and foraging, habitats utilized, and reproductive behavior. This information can be leveraged to inform wildlife movement models. The literature for modeling wildlife movement spans several decades, and a variety of approaches have been employed. A selection of examples of previous applications of wildlife movement models are described briefly below, including RPS ASA's WILDMAP model.

Ford et al. (1982) developed demographic and foraging models to simulate the response of colonially breeding seabirds in the Bering Sea to perturbations such as oil spills. Using information on the observed distribution of birds, the length of time that individuals spend foraging, and daily energy requirements, the foraging model simulated the pattern of movement and distribution of foraging birds at sea.

Using available census and telemetry data for sea otters, Brody (1988) developed a model to simulate the risks of oil spills to sea otters in California. This model coupled a population model with models of sea otter distribution and movements. Behavioral parameters were incorporated (such as home range, male territoriality, seasonal migration, etc.) and movements of otters were simulated on a daily basis for up to 30 days.

Arnold and Holford (1995) constructed a simple simulation model to predict geographical movements of demersal fish on the European continental shelf from tidal-stream vector data and fish behavior information (e.g., swimming speed, vertical migration patterns). The model is able to predict the tracks of individual fish, as well as the distribution of populations. The model described in Arnold and Holford (1995) is deterministic, but the authors note that a stochastic component of fish behavior could be included to allow for the effects of random dispersal.

Recently, the BioDiversity Research Institute received a grant from the U.S. Department of Energy to model bird, sea turtle, and marine mammal densities and movements on the mid-Atlantic continental shelf. The objective of this study is to produce the necessary data to inform siting and permitting for offshore wind development in the region. This will be accomplished by collecting survey data, as well as developing hierarchical models to examine abundance and spatial patterns.

In RPS ASA's (formerly Applied Science Associates, Inc.) first migration project for BOEM (formerly the Minerals Management Service), WILDMAP was developed to model whale migrations in Arctic waters (north of Unimak Pass) (Reed et al., 1987a, 1988; Jayko et al., 1990). The model analyzed each species separately, as different behaviors dictated different distributions. Bowhead whales remain in these northern waters the entire year; therefore, the model simulated the annual migration of the whales from the Bering Sea to the Canadian Beaufort Sea and back again. Since gray whales travel as far south as Mexico in the winter, their migration was only simulated from approximately April through December, when the whales are present in the Bering Sea. The movement of whales was simulated using a random walk algorithm which stochastically follows a migratory pathway.

The next year, Applied Science Associates further developed WILDMAP and applied it to northern fur seal population dynamics, which included age- and sex-specific mortality and reproductive rates with density-dependent control of pup and juvenile mortality. Applied Science Associates combined its WILDMAP migration and behavior model (French et al., 1989) with population modeling (French and Reed, 1990) to evaluate the magnitudes of potential impacts of oil spills, as well as recovery time (Reed et al., 1987b; 1989). Movement patterns of seals within the Bering Sea are functions of date, sexual status, and age, conforming to probability distributions based on field observations of their movements and timing. Movements on and off land at known rookeries were included in the simulations.

WILDMAP Model Description

WILDMAP, RPS ASA's wildlife movement (migration and behavior) model, utilizes life-history information, such as nesting/breeding and foraging locations, to model the distributions and relative densities of individual species. The model is supported and ground-truthed by presence/absence, abundance, frequency, and spatial observational data.

WILDMAP produces estimates of time-varying abundances. To generate these abundances, behavioral and sightings information are used to determine behavioral choices at any given instant and location. Behavioral components integrated into the model include daily behaviors for foraging, sleeping or roosting, and travelling to preferred areas for these activities; and seasonal behaviors for breeding, nesting, hibernating, and migrating. Additionally, preferred habitats for each of the listed behaviors, based on sightings and literature, are mapped and given probabilities of attracting an individual to that location. The model then tracks movements within the boundaries of the study area (a geographical map of habitat characteristics over a large enough domain to include normal movement patterns for the species), as well as migrations in and out of the modeled area. By modeling movements of a local population, relative densities of the species (in space and time) can be calculated from model results and compared to observational data for calibration and verification.

WILDMAP moves Lagrangian elements (LEs) representing individual animals (or groups of individuals) based on rules defined by the model and user inputs. Major user inputs are life history traits and three types of usage grids. The first type of grid is a foraging or feeding map (see Figure 8 for an example foraging map for northern fur seal adult females in the Bering Sea). In this grid, foraging areas are identified and rated based on preferences and traits of the species and other factors, such as distance from sleeping locations. The second type of grid is a sleeping or resting map. Similar to the foraging map, this marks the locations where popular resting spots are found. To travel between foraging and sleeping locations, they are assigned a travelling grid which identifies where travel is allowed (e.g., marine mammals cannot travel over land). The last grid is the nesting or spawning grid where nesting sites are identified.

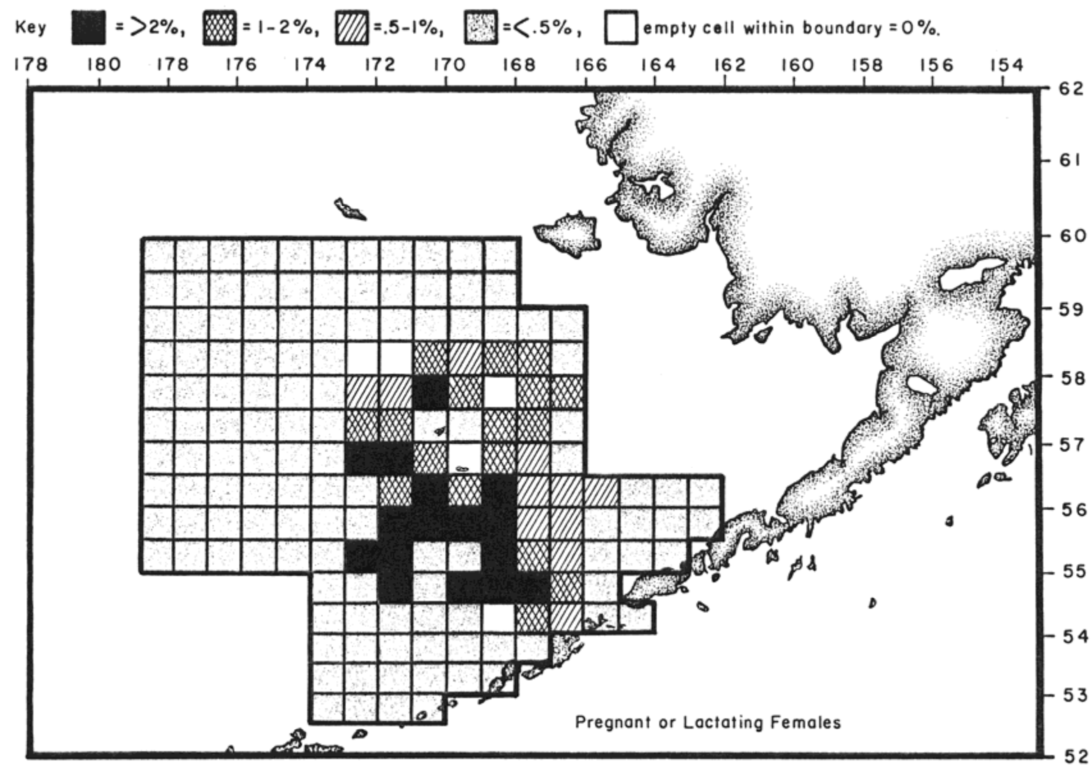


Figure 8. Example foraging grid. Probability of foraging by pregnant or lactating female northern fur seals. Reproduced with permission from French et al., 1989.

WILDMAP is designed to run for a year or less, simulating the yearly cycle of wildlife within an area of interest. The model is initialized by creating a migration event into the area or, if the species is a resident, a biologically appropriate time. After the population is in the area, other life-history parameters are identified to define time spent foraging and sleeping or resting. As the simulation continues, different events can be depicted, such as nesting and rearing young. For all of the behavior changes, median dates are entered into the model and then the simulated population will undergo those changes based on either a normal distribution curve or an even distribution around the median date.

For example, northern fur seals move through Unimak Pass, Alaska to forage in the Bering Sea during the summer months. The timing of the migration in and out of the region can be inferred from observational data. Figure 9 shows an example of the distribution of arrival and departure times of pregnant adult females from the French et al. (1989) study; this information is fed into the WILDMAP model.

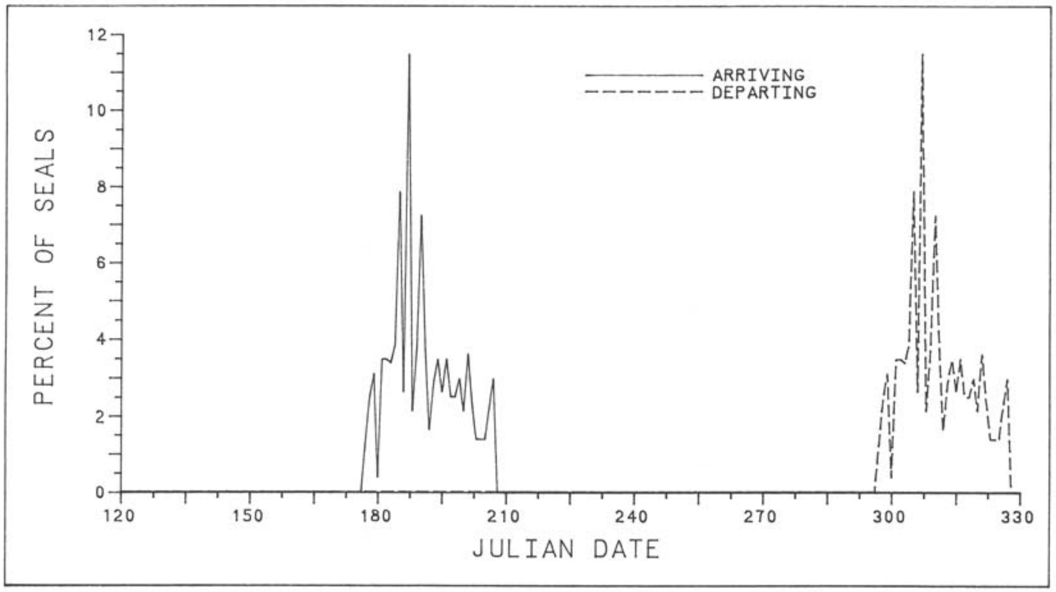


Figure 9. Distribution of arrival and departure times for pregnant adult female fur seals used in WILDMAP simulations in the French et al. (1989) study. Reproduced with permission from French et al., 1989.

The model also keeps track of the status of the population. When initialized, the model calculates the percent of the population that is immature, reproductively mature, or post-reproductive; and during the simulation the age of the LE dictates when it switches between these three main statuses. Additionally, immature individuals can be given specific behaviors, such as nest-bound, following the parent, or independent. Reproductive adults can be without young, or associated with one of the immature statuses; these statuses are dictated by age of the young. The population on the whole may also be modeled with a death rate. The instantaneous daily mortality rate is calculated from the user-input annual survival rate. In future applications of the model, additional mortality components may be added to estimate losses due to an external factor (e.g., an incidental death rate at turbine fields).

Figure 10 shows a sample of the WILDMAP-simulated distribution of fur seals at sea from May to December from the French et al. (1989) study. The figures are arranged chronologically and show the migration and movement of various components of the population (e.g., immature males, pregnant females) over time. These figures show that fur seals arrive as early as May to the foraging areas, but only males are present at this time. Females begin to enter the Bering Sea through Unimak Pass in June, and all components of the population have returned by July and are moving between the rookeries and feeding areas at sea. By November, the exodus of seals through Unimak Pass is underway and apparent in the Figure 10. Adult females and pups of both sexes are the last to leave the Bering Sea.

The panels of Figure 10 only show a small sample of the modeled population, but at the end of the simulation (either one year from the start or when all the individual have migrated out of the area) the results for the entire population can be used to calculate the relative average densities of individuals (seasonally or annually) in each grid cell. These results can be exported as grid files to be read into the EVI model framework.

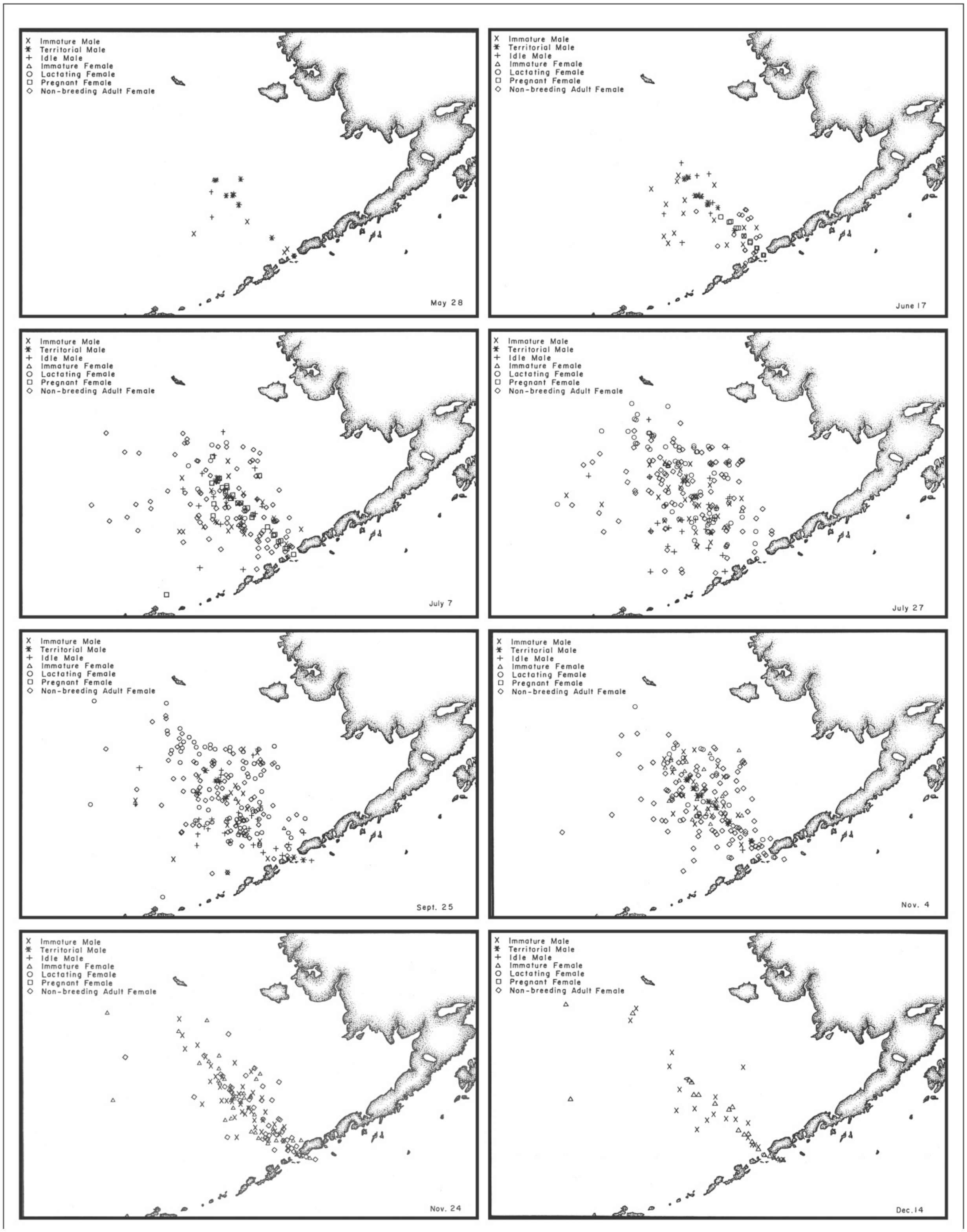


Figure 10. Sample of the WILDMAP-simulated northern fur seal population by sex and reproductive status (May-December). Reproduced with permission from French et al., 1989.

2.3.2.3. Resource Categories with Missing Information

For some resource categories, little or no spatial information may be available. In these cases, information is even too scarce to warrant the application of a movement model. Recognizing the data gap is important, and results can be framed with the missing resource caveat. For instance, spatial information on bats in the RI Ocean SAMP area was unavailable.

Bats are commonly considered terrestrial mammals, but migratory species have been found to migrate over open oceans; many sightings, both confirmed and anecdotal, of flocks flying over open water have been recorded over the past century (Cryan pers. comm., 2009). Cryan and Brown (2007) investigated the occurrence of hoary bats on one of the Farallon Islands, an island off the coast of California used as a stopover point. Their study confirmed the migration of bats over open water and suggested that occurrences could be predictable based on weather and other environmental conditions. Bats have also been observed seasonally on Bermuda, indicating that they are likely migrating over a large expanse of open water (Van Gelder and Wingate, 1961). In the Northeast, bat observations include:

- Periodic sightings in the spring and fall at the lighthouse on Mount Desert Rock, thirty miles (48 km) off the coast of Maine;
- Oceanic sighting around the islands of coastal Maine and the Gulf of Maine, off Nova Scotia, and off Montauk Point New York; and
- Observation closer to shore over Long Island Sound, off Sandy Hook New Jersey, across Cape Cod and Cape Cod Bay, and Nantucket Sound (Cryan, pers. comm., 2009).

Bats may be a sensitive component of the offshore ecosystem potentially affected by ORE development, but sufficient data are not available at this time to include them in the application of the CIM-Eco model. However, if data become available in the future, a bat category can easily be incorporated into the model framework as an additional resource category.

2.4. Example Results

2.4.1. Category EVMs

This section contains a series of example category EVMs generated for each ecological category, based on input data (see Appendix B) and weightings from the RI Ocean SAMP project. These maps represent annual averages for each category, but a series of seasonal EVMs could also be generated using seasonal input data.

2.4.1.1. Benthic Ecosystem

Scope for Growth was used as a proxy for the benthic ecosystem component, as detailed benthic community analyses are labor intensive and difficult to obtain over a wide geographic area. As more detailed descriptions of the benthic communities are completed, this category EVM can be modified.

The benthic ecosystem category EVM was created using the weighting scheme in Table 1. A value of 0.5 was selected as the productivity index (*PI*) level corresponding to the highest ecological value. This is based on the assumption that in the RI Ocean SAMP area there is a humpback-shaped relationship between biodiversity and Scope for Growth, where moderate Scope for Growth values are associated with the highest biodiversity (Figure 11). A weight of 2 was assigned at this level because the benthic production in this region is a small component of the overall ecosystem. A weight of 1 was assigned at *PI*=1. The actual relationship between benthic productivity and biodiversity in the RI Ocean SAMP area has not been determined, and all of these values can be refined if more detailed information becomes available.

Table 1

Weighting scheme for benthic ecosystem in the category EVM

Weighting Criteria:	Productivity Index (*PI*) Value where Ecological Value is Highest	Weight at *PI* = Highest Ecological Value	Weight at *PI* = 1	Data Robustness
Scope for Growth	0.5	2	1	1

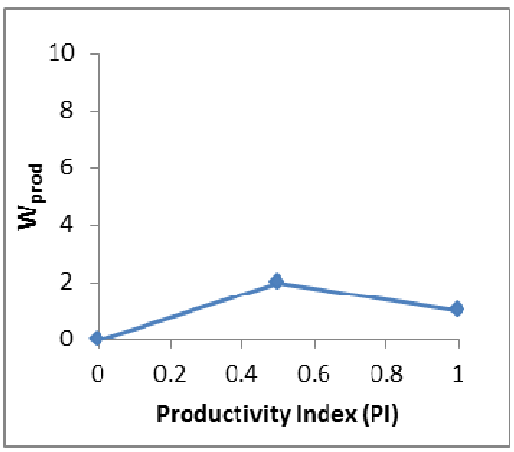


Figure 11. Weighting function for benthic production in the category EVM.

The resulting benthic ecosystem category EVM shows an area of low ecological value at the mouth of Narragansett Bay. The areas of highest ecological value are around Block Island and a few patches to the east (Figure 12).

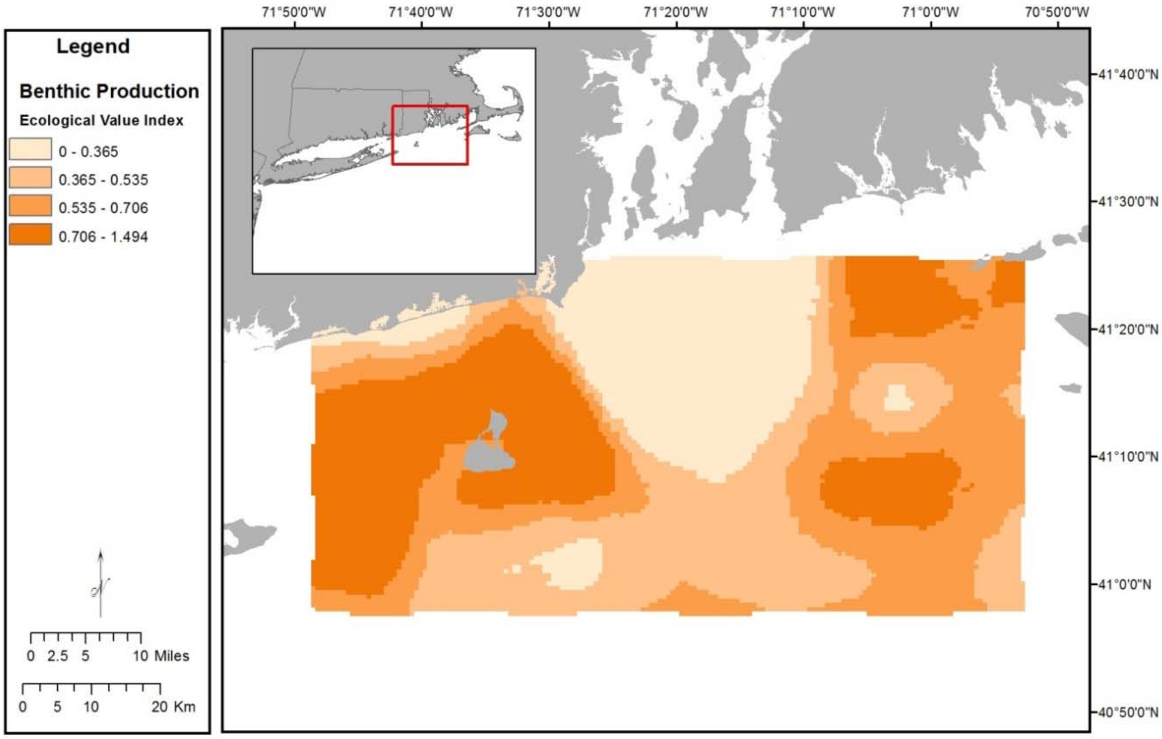


Figure 12. Annual category EVM for benthic production, weighted based on values in Table 1.

2.4.1.2. Pelagic Ecosystem

The pelagic ecosystem category EVM was created using the weighting scheme in Table 2. A value of 1 was defined as the productivity index (*PI*) level corresponding to the highest ecological value because over-production of the pelagic environment is not a common phenomenon in this area. A value of 2 was assigned for the importance at this level because the pelagic production in this region is a small component of the overall ecosystem. Because the weighting function described by the values in Table 2 is a continuously-increasing function with a maximum of 2 (Figure 13), the weight applied at *PI* = 1 defaults to 2.

Table 2

Weighting scheme for pelagic ecosystem in the category EVM.

Weighting Criteria:	**Productivity Index (*PI*) Value where Ecological Value is Highest**	**Weight at *PI* = Highest Ecological Value**	**Weight at *PI* = 1**	**Data Robustness**
Chlorophyll *a* Production	1	2	2	1

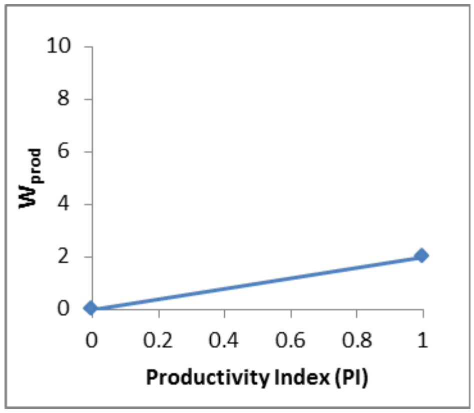


Figure 13. Weighting scheme for pelagic production in the category EVM.

Remotely sensed surface chlorophyll *a* data show that the highest concentrations occur during the summer, close to shore. When averaged over the year, the ecological value of chlorophyll *a* concentration (as a proxy for the pelagic environment) is generally higher closer to shore and lower in the offshore environment (Figure 14).

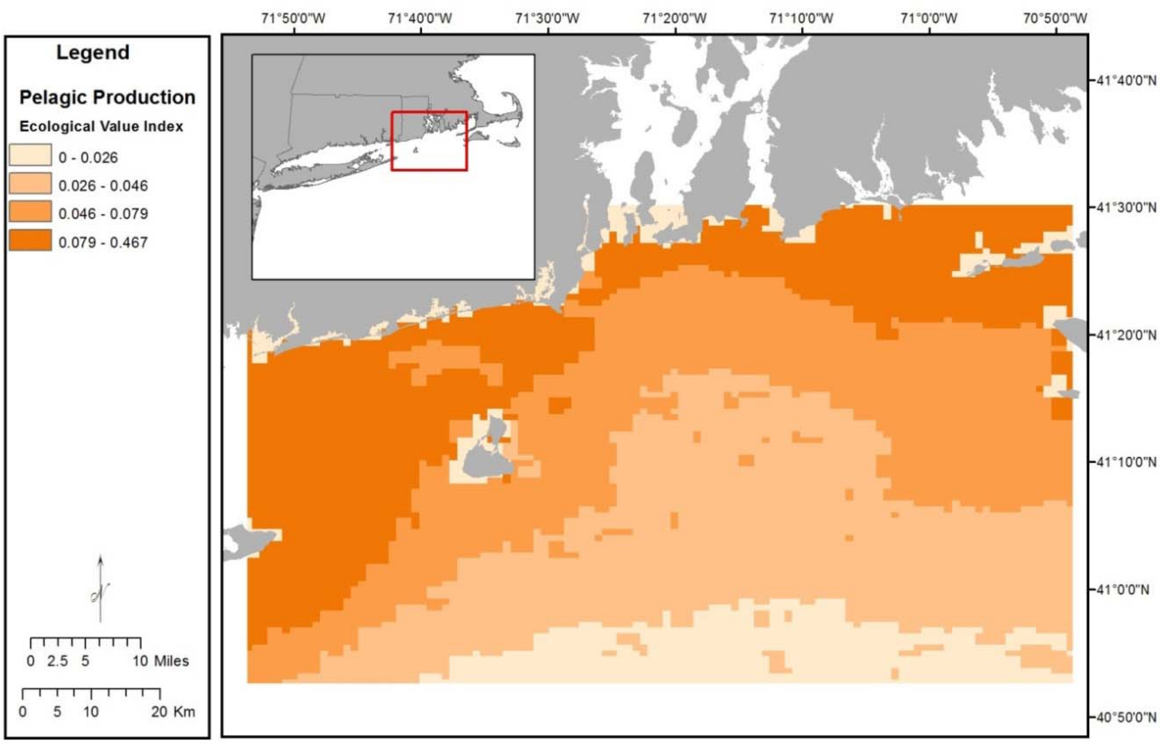


Figure 14. Annual category EVM for pelagic production, weighted based on values in Table 2.

2.4.1.3. Fish and Large Invertebrates

The ten groups of fish and invertebrate species used in the RI Ocean SAMP were combined into a category EVM (Figure 15) using the weighting scheme in Table 3. In the annual ecological value map of fishes and large invertebrates, areas of high relative ecological value fall into three general regions: south of the mouth of Narragansett Bay, in intermediate depths in the eastern portion of the RI Ocean SAMP study area, and southeast of Montauk, New York (Figure 15). Because this map is made up of ten species groups with varying habitat preferences, one would not expect to see a clear trend associated with a particular sediment/habitat type. However, there is a general trend of higher ecological value closer to shore than in the offshore environment.

Table 3

Weighting schemes for fish and invertebrate groups included in the category EVM.

Weighting Criteria:	Regional-Global Importance	Protection Status	Data Robustness
Lobster	4	4	1
Sea Scallop	4	2	1
Squid	4	2	1
Demersal fish	4	4	1
Flatfish	6	4	1
Baitfish	2	2	1
River Herring/Smelt	6	6	1
Medium Gamefish	6	4	1
Large Gamefish	4	3	1
Skates	6	3	1

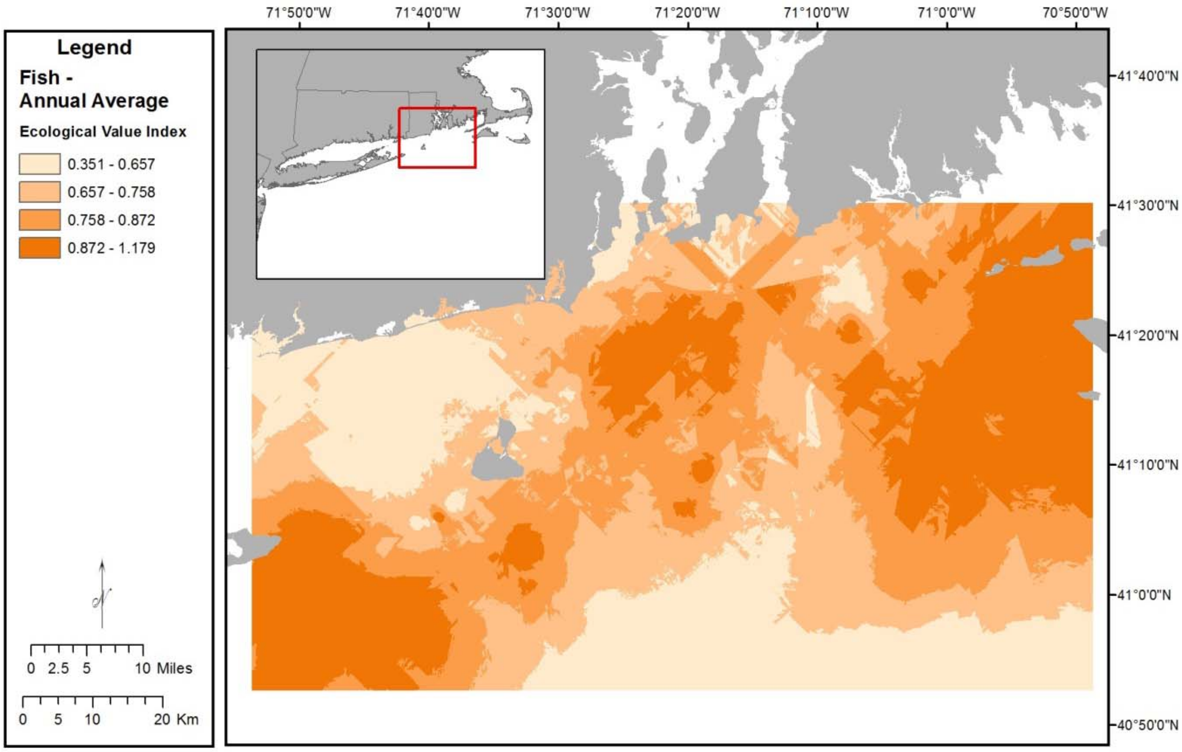


Figure 15. Annual category EVM for fish and large invertebrates, weighted based on values in Table 3.

2.4.1.4. Birds

The bird groups were combined into a category EVM (Figure 16) using the weightings in Table 4. It is important to note that the modeled surfaces only represent foraging areas for the species evaluated, and do not include movement corridors. Additionally, fall data for loons and seaducks were unavailable, thus spring surface-density models were used as a proxy for fall surface-density models for these two species groups.

Table 4

Weighting schemes for bird groups included in the category EVM.

Weighting Criteria:	Regional-Global Importance	Protection Status	Data Robustness
Loons	2	4	1
Alcids	2	4	1
Gulls	2	2	1
Gannets	2	2	1
Sea Ducks	1	3	1
Shearwaters	1	3	1
Terns	2	6	1
Petrels	1	2	1

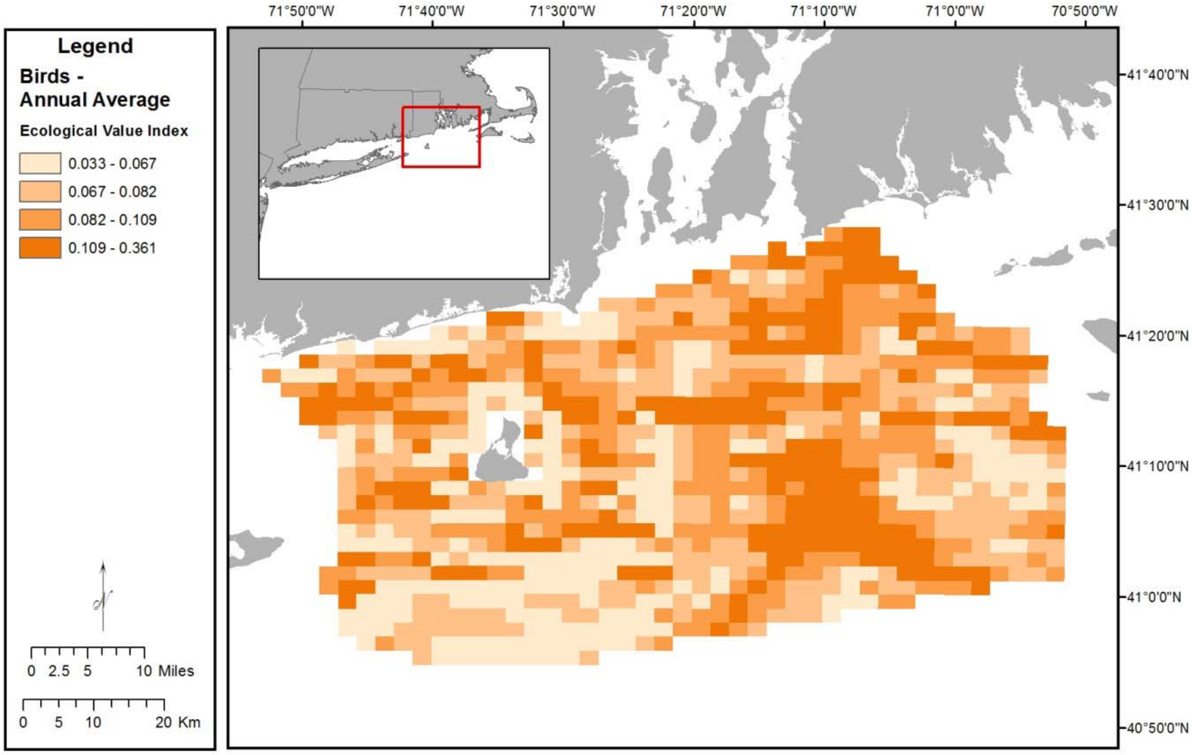


Figure 16. Annual category EVM for birds, weighted based on values in Table 4.

In the annual ecological value map for birds (Figure 16), areas of high relative ecological value are distributed throughout the Ocean SAMP area, with no obvious overall pattern. This lack of a strong overall trend is not surprising given that the eight bird groups included in the EVM analysis represent species with a variety of habitat preferences. For example, based on Paton et al.'s (2010) literature review, most sea ducks typically forage in waters that are 5 to 20 m deep where bivalves and other forage are available; gannets and loons are piscivorous specialists and tend to occur in areas where water depths are 30 to 45 m deep and <35 m deep, respectively; and within the alcid group, razorbills were consistently found in shallower waters closer to the mainland; common murres primarily occur in the central regions of the RI Ocean SAMP region, and dovekies occur offshore over deeper depths out to the continental shelf.

It is important to note that the inverted V-shaped area of high ecological value that appears in the southern portion of Rhode Island Sound (Figure 16) can be attributed to the modeling approach that was used to generate a continuous topology for the bird group input layers. As discussed in Section 2.3.1.2, this pattern is likely being driven by the predictive model based on depth and distance from shore, rather than a true underlying pattern in bird abundance.

2.4.1.5. Marine Mammals

Eleven species of marine mammals were included in the RI Ocean SAMP analysis. The weighting schemes used for creating the category EVM (Figure 17) are listed in Table 5. The North Atlantic right whale, which is found in the RI Ocean SAMP area during its spring and fall migration, has a higher influence on the EVMs than other marine mammals because of its smaller geographic range relative to the other species.

Table 5

Weighting schemes for marine mammal species included in the category EVM.

Weighting Criteria:	Regional-Global Importance	Protection Status	Data Robustness
Bottlenose Dolphin	1	6	1
Fin Whale	1	10	1
Harbor Porpoise	1	6	1
Humpback Whale	1	10	1
Minke Whale	1	6	1
Pilot Whales	1	6	1
North Atlantic Right Whale	6	10	1
Short-beaked Common Dolphin	1	6	1
Seals	1	6	1
Sperm Whale	1	10	1
Atlantic White-sided Dolphin	2	6	1

The annual EVM for marine mammals shows a strong offshore/nearshore trend, with higher relative ecological value with increasing distance from shore (Figure 17). This pattern is primarily influenced by federally-listed endangered species (i.e., fin, humpback, North Atlantic right, and sperm whales). In the nearshore, the waters surrounding Sakonnet Point have slightly higher relative ecological value than other areas along the Rhode Island mainland coast. This is mainly driven by the presence of seals and harbor porpoise.

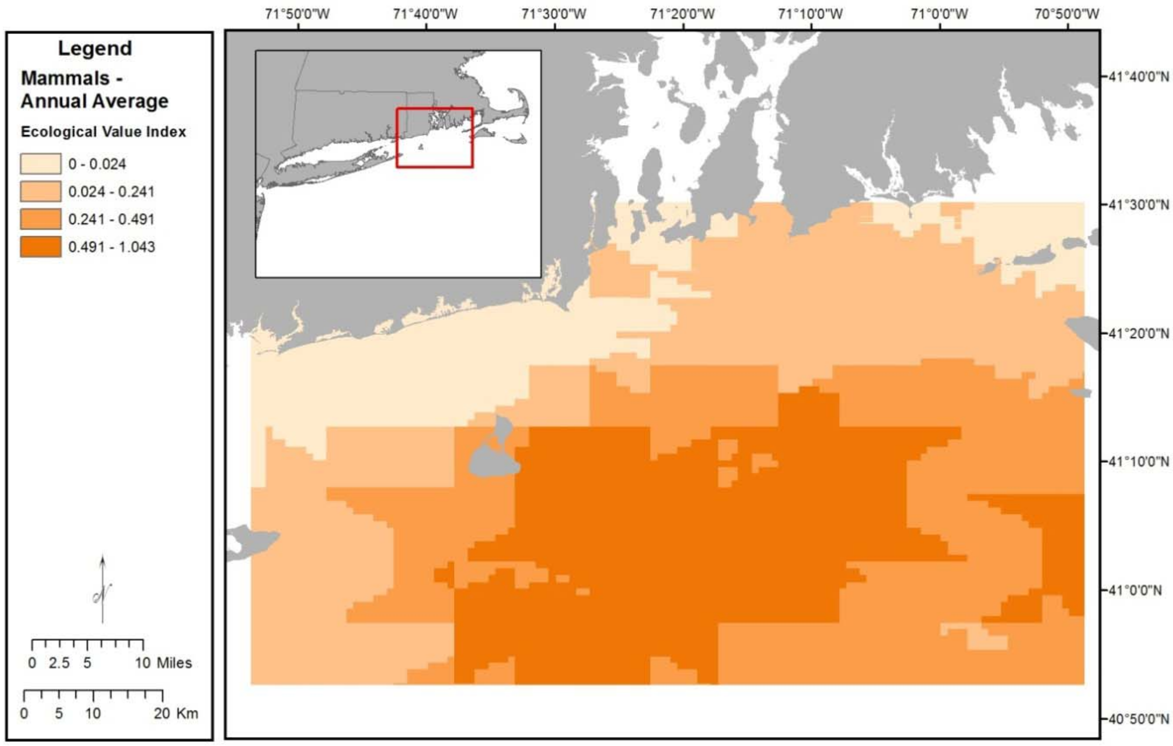


Figure 17. Annual category EVM for marine mammals, weighted based on values in Table 5.

2.4.1.6. Sea Turtles

The two sea turtle species used in the RI Ocean SAMP analysis were combined into a category EVM (Figure 18) using the weightings in Table 6. The one difference in the weightings between the two species arises in the Protection Status category, as leatherbacks are federally endangered and loggerheads are federally threatened in this region. The annual ecological value map reinforces the trend that loggerhead and leatherback sea turtles are generally found farther offshore, with highest relative ecological value in the offshore portion of the RI Ocean SAMP (Figure 18). Leatherback turtles are a stronger driver of the ecological value distribution than loggerhead turtles due to their status as a federally-listed endangered species. Kemp's ridley and green sea turtles were not included in this analysis because of a lack of sufficient data. They are both coastal species, and inclusion of these species in the EVM would likely alter the apparent spatial trends.

Table 6

Weighting schemes for sea turtle species included in the category EVM.

Weighting Criteria:	Regional-Global Importance	Protection Status	Data Robustness
Loggerhead	1	8	1
Leatherback	1	10	1

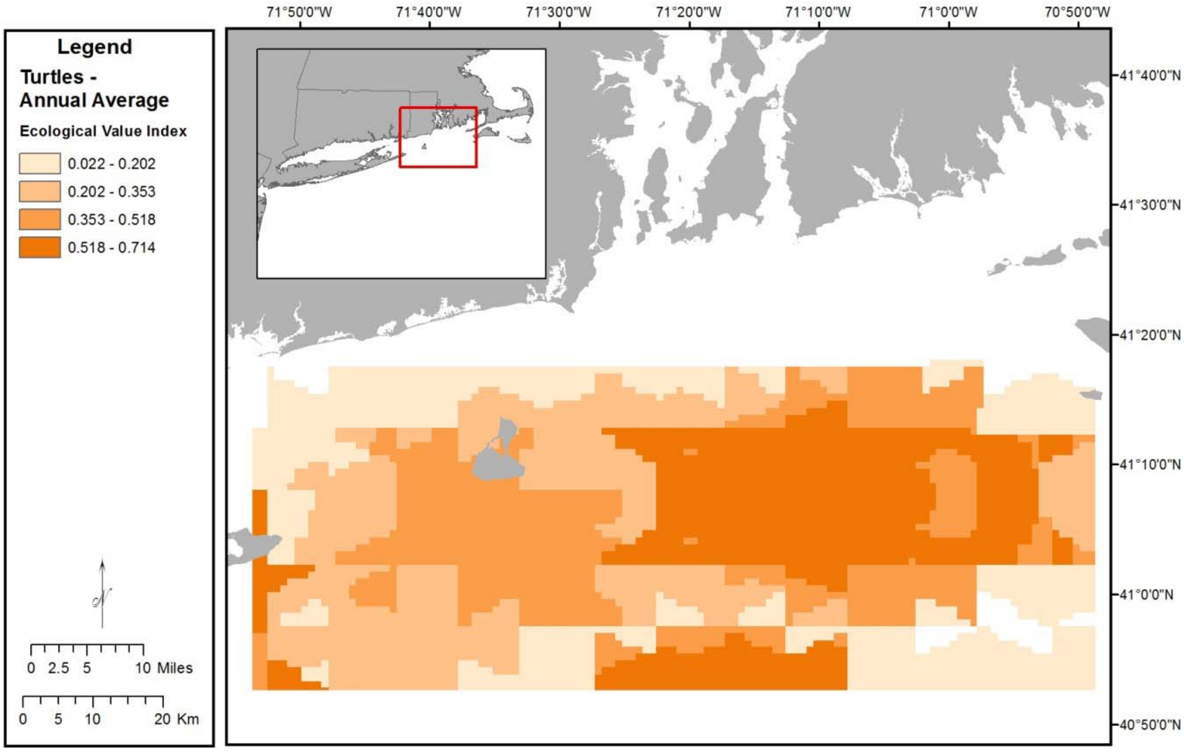


Figure 18. Annual category EVM for sea turtles, weighted based on values in Table 6.

2.4.2. Composite EVI

Figure 19 depicts the composite EVI for all of the resources included in the RI Ocean SAMP study, on an annual basis. In general, this EVI demonstrates a pattern of lower relative ecological value in the nearshore environment and higher relative ecological value in the offshore environment, with the areas of highest relative ecological value located to the southeast of Block Island and in a large area in the southeast of the RI Ocean SAMP region. This pattern is primarily being driven by the presence of marine mammals and turtles and their status as federally-protected species.

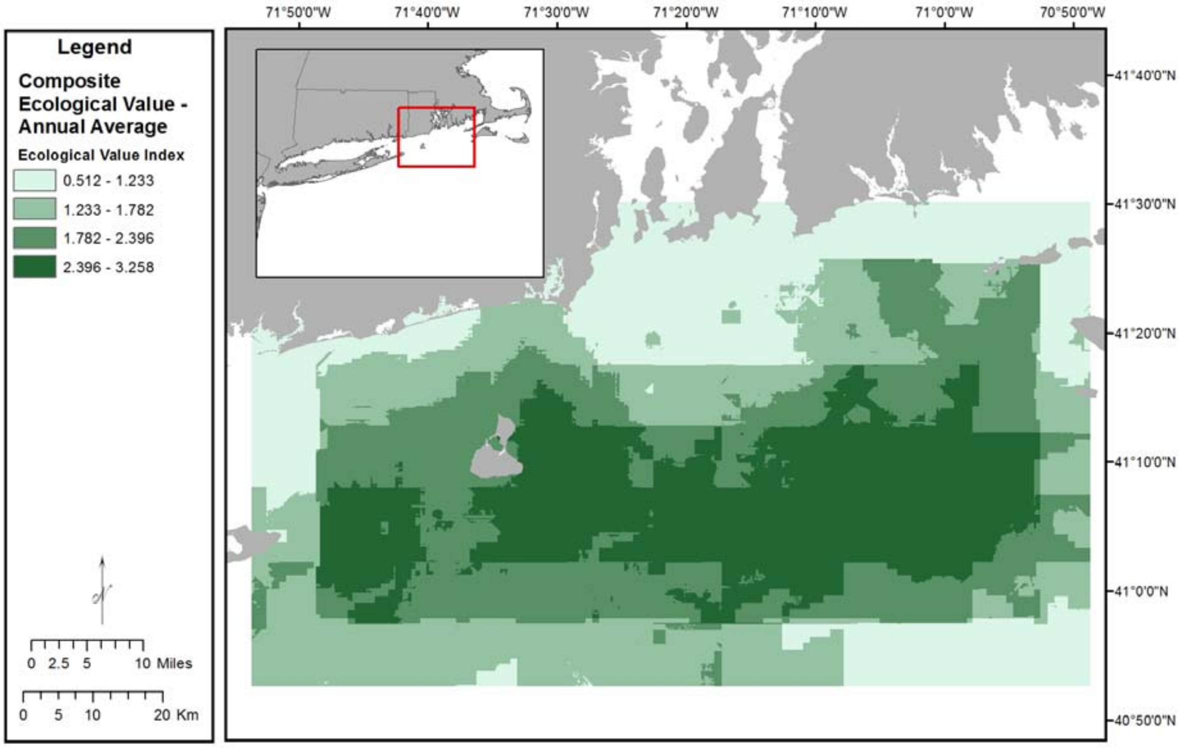


Figure 19. Annual Composite EVI of ecological value for all resources.

While protected species are likely to be an important factor in the regulatory review of a proposed offshore project, the marine mammal and turtle species found in the RI Ocean SAMP region have large geographic ranges and do not have critical habitat within the study area. Assessing these migratory species at a local scale (i.e., within the relatively small RI Ocean SAMP region) may lead to overestimation of the importance of the local area to that species. See Section 2.3.1.1 for further discussion of issues of scale.

2.4.3. CIM-Eco

Using information from the Effects Decision Tree, we applied two example impact scenarios to generate example CIM-Eco maps. For the first scenario, we evaluated a hypothetical demonstration-scale wind development with monopile foundations, to be sited within the Block Island Renewable Energy Zone (shown on Figure 20). The impact weights for each ecological category are listed in Table 7. The anticipated adverse effects for this demonstration-scale project are minor for all categories, with the exception of the pelagic ecosystem, for which no adverse effects are expected. The resulting CIM-Eco map is shown in Figure 20. When the potential impact of the development is considered along with ecological value, the offshore/nearshore pattern is still apparent, and is still strongly driven by the presence of marine mammals and sea turtles (as expected, given the similarity of the impact-based weights for the categories). Within the Block Island Renewable Energy Zone, CIM-Eco index values are very similar, but there is slightly less relative ecological value/potential for impact value in the western-most portion of the zone.

Table 7

Impact weightings applied for a hypothetical demonstration-scale wind energy development with monopile foundations.

Ecological Category:	Relative Impact Weighting
Benthic Ecosystem	2
Pelagic Ecosystem	1
Birds	2
Fish and Large Invertebrates	2
Marine Mammals	2
Sea Turtles	2

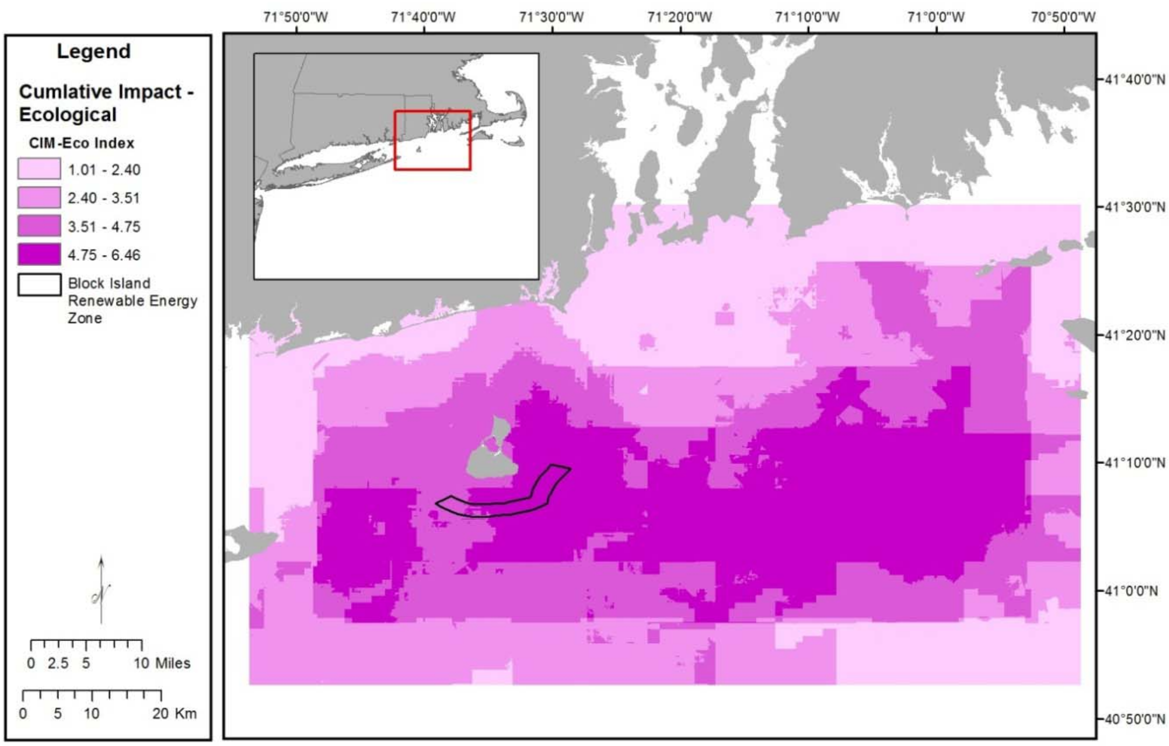


Figure 20. Example CIM-Eco results for a demonstration-scale wind energy development with monopile foundations.

For the second scenario, we evaluated a hypothetical commercial-scale wind development with lattice foundations, to be sited within the Rhode Island-Massachusetts Area of Mutual Interest (AMI, shown on Figure 21). The impact weights for each ecological category are listed in Table 8. The resulting CIM-Eco map is shown in Figure 21. Again, the results are strongly driven by the presence of marine mammals and sea turtles, and there is relatively less ecological value/potential for impact in the nearshore versus further offshore. Because the AMI is located in the offshore environment, relative CIM-Eco index values are similar within the area. However, the northern-most and eastern-most blocks have the lowest relative ecological value/potential for impact, and may be the most desirable locations within the AMI to site a facility of this type, at least from an ecological standpoint.

These maps only represent the CIM-Eco portion of the overall Siting Evaluation Model, and are intended to be evaluated in conjunction with the CIM-HU index, Technology Development Index (TDI, discussed in Section 4), and other relevant information.

Table 8

Impact weightings applied for a hypothetical commercial-scale wind energy development with lattice foundations.

Ecological Category:	Relative Impact Weighting
Benthic Ecosystem	8
Pelagic Ecosystem	1
Birds	6
Fish and Large Invertebrates	4
Marine Mammals	8
Sea Turtles	8

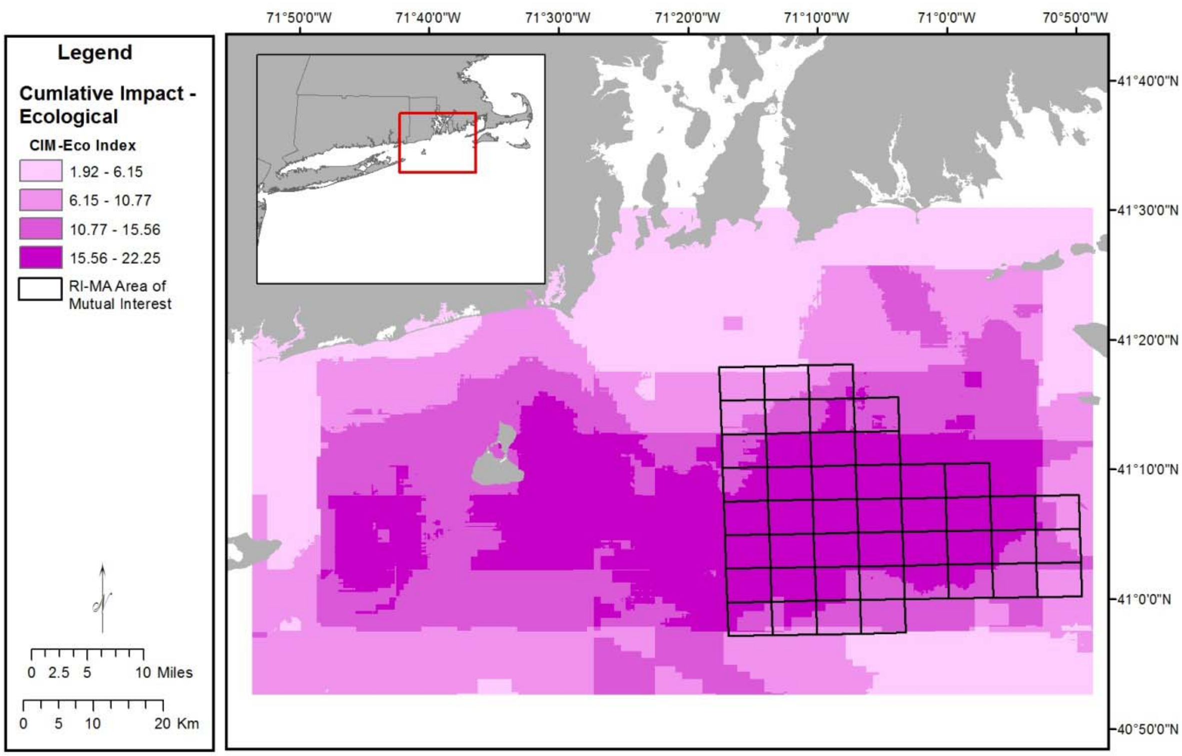


Figure 21. Example CIM-Eco results for a commercial-scale wind energy development with lattice foundations.

It is important to note that the scale of the CIM-Eco index shown on these maps varies depending on the magnitude of the potential impact. For example, the darkest color on Figure 20 represents CIM-Eco index values of between 4.76 and 6.46, whereas the darkest color on Figure 21 represents values between 15.56 and 22.25. When evaluating several different potential development types, these differences in scale reflect the different levels of impact between the development types. While this information is useful for most analyses, there may be a situation in which the user wants to compare the maps on the same scale. To accomplish this, the CIM-Eco index results could be normalized to the maximum value in the layer, or the scale of the legend could be changed to make the values associated with each color consistent between each map. For example, Figure 22 shows the results from Figure 20 on the same color scale as Figure 21. In this figure, it is now readily apparent that the anticipated impacts from a demonstration-scale wind energy facility are less than those expected for a commercial-scale facility of the same type.

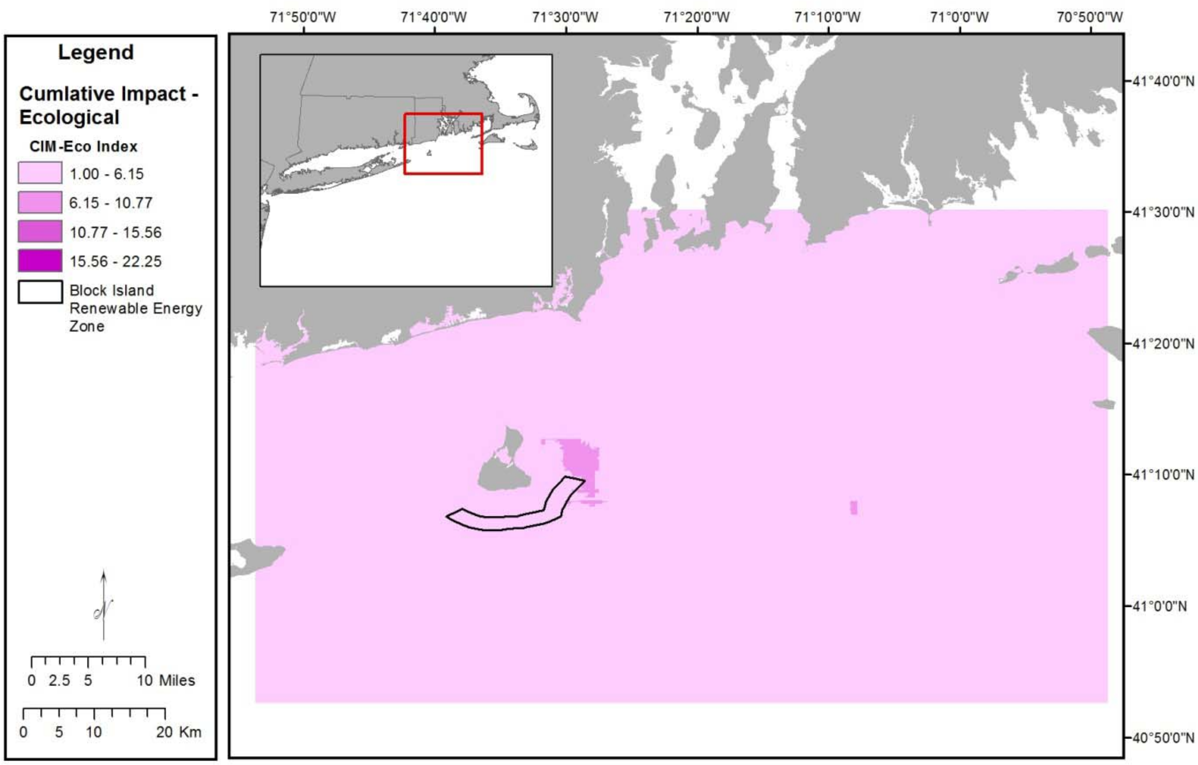


Figure 22. Example CIM-Eco results from Figure 20, shown on the same scale as Figure 21.

3. CUMULATIVE IMPACT MODEL – HUMAN USE

The results of the CIM-Eco framework may be combined with the results of a parallel human use model, CIM-HU, which addresses the impacts of development on human uses of the marine environment. The Human Use Index (HUI), parallel to the EVI, would be based on relative weighting of socioeconomic categories, which are in turn comprised of components based on data layers. The HUI/CIM-HU analysis would follow the same general procedure/calculations as described for the EVI/CIM-Eco analysis in the preceding sections. This section describes the overarching CIM-HU framework. Implementation of this framework was not included in the scope of the current project.

In the EVM framework, ecological data inputs representing various components (e.g., individual species) are integrated into a series of category-level EVMs (e.g., birds) using a variety of weighting factors. The EVMs are then summed in to an EVI. In the HUI framework, the category-level maps would consist of the following categories (at a minimum):

- Cultural Resources (e.g., archaeological sites)
- Fishing and Aquaculture
- Commercial Traffic
- Recreational Boating
- Other Marine Recreational Areas (e.g., scuba diving sites)
- Department of Defense Use Areas
- Dredge Spoil Areas
- Existing Infrastructure (pipelines, telecommunications, energy facilities, etc.)

The BOEM/NOAA Multipurpose Marine Cadastre has data layers available for several of these categories (e.g., submarine cables, pipelines, shipping lanes, energy facilities). Each of these categories may be made up of one or many individual components. For example, the Fishing and Aquaculture category would be made up of components reflecting commercial fisheries (e.g., by gear type or target species), recreational fisheries (e.g., known fishing grounds, artificial reefs), and aquaculture sites.

In the EVMs, the individual components are based on measures of aggregation; for the HUI, the assessment metric would be specific to the given components/categories, and could consist of a continuous topology (e.g., maps of gridded fisheries landings data, ship traffic density, archaeological sensitivity) normalized to a 0 to 1 scale, or a layer containing delineated features (e.g., existing submarine pipelines, dredge spoil areas, recreational fishing grounds), coded on a 0 to 1 scale.

For example, submerged shipwrecks are one component of the Cultural Resources category. The input data for this component could consist of a point-density surface of shipwrecks, generated from Automated Wreck and Obstruction Information System (AWOIS) or other data (Figure 23) or a probability surface of shipwrecks (Figure 24). Similar layers could be included for other known cultural/historic sites. Further guidance on creating input layers appropriate for evaluating cultural resources is provided in the Year 1 Deliverable entitled "Task 4 – Standardized Protocols for Assessing the Effects of Offshore Alternative Energy Development on Cultural Resources."

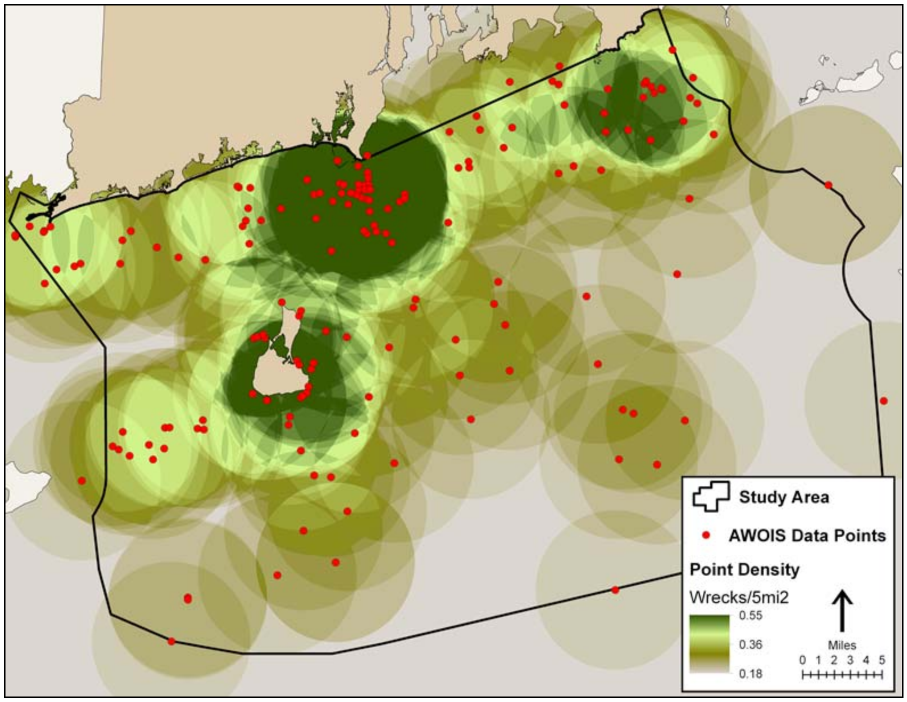


Figure 23. Example point-density surface generated from AWOIS data (reproduced from the Task 4 Report, figure 3 therein). This layer would need to be normalized to a 0 to 1 scale prior to incorporation into the HUI.

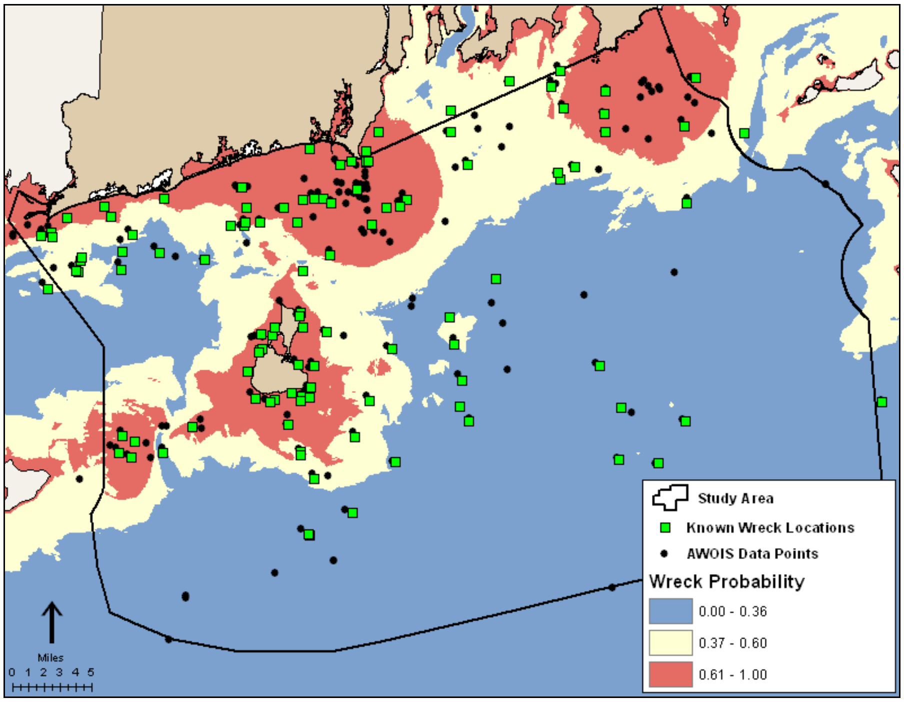


Figure 24. Probability surface displayed with known wreck locations and AWOIS data points (reproduced from the Task 4 Report, figure 5 therein).

If information on individual components is not available, a sensitivity map resulting from an Archaeological Sensitivity Analysis could be used to represent the Cultural Resources category. As discussed in the Task 4 Report, Archaeological Sensitivity Analysis is a technique used by archaeologists and historians to divide an area into zones of archaeological sensitivity, based on historic, archaeological, geographic information system (GIS), geophysical, and site-specific studies as interpreted by an experienced professional archaeologist and/or historian. Those zones generally range from Highest Sensitivity (areas that contain known cultural resources that are on, or have been determined eligible for inclusion in, the National Register of Historic Places) to Lowest Sensitivity (areas that have experienced low levels of documented human activity or that have experienced extensive disturbance).

Individual components would be weighted based on their relative human-use value and summed to the category-level. We envision using a trio of weighting schemes (similar to the component-level weighting schemes in the EVI analysis, Section 2.2.1.1), reflecting relative importance, regulatory protection status, and data robustness. These weighting schemes, would be set on a relative scale from 1 (no extra weight) to 10 (highest weight).

For the relative importance scheme, weightings could be assigned based on management priorities, stakeholder input, or economic measures of value such as willingness-to-pay, travel cost, consumer surplus, commercial revenues or profits, etc. For example, a manager evaluating the siting of a particular ORE development may weight a commercial-shipping-lanes layer highly if the feature is incompatible with the type of proposed development (e.g., a commercial-scale wind farm).

The regulatory protection status weighting scheme would add further weight to components that have an additional layer of regulatory protection. For example, cultural resources are protected under a variety of regulations, including the National Historic Preservation Act, the American Antiquities Act, the Archeological Protection Act, the Sunken Military Craft Act, the Abandoned Shipwreck Act, the National Environmental Protection Act, and applicable state law.

The data robustness scheme would follow the same general structure as that outlined in Section 2.2.1.1.

After applying these weighting schemes to generate the category-level maps, the results are summed to create the HUI. Weighting factors quantifying the potential impacts of ORE development are then used to modify the category weights in the HUI in order to generate the CIM-HU index. We envision that a parallel to the Offshore Renewable Energy Effects Matrix could be generated for the human use categories to guide the application of impact weightings.

4. CUMULATIVE USE EVALUATION MODEL AND SITING EVALUATION MODEL

The CIM-Eco and CIM-HU indices described in Sections 2 and 3 can be combined to create the Cumulative Use Evaluation Model (CUEM). Using this tool, a decision maker could evaluate the impacts of an offshore development, and ideally, the topology of the CUEM composite index would identify areas most suitable for facility siting (from an ecological and human use perspective) and help inform the analysis of alternatives pursuant to the National Environmental Policy Act. However, because other factors (such as technical feasibility and costs) are also important considerations in the siting of an ORE facility, the CUEM framework and approach is designed to be part of a larger siting evaluation framework for decision-makers, referred to as the Siting Evaluation Model (SEM).

As shown in Figure 25, the SEM also includes the Technological Development Index (TDI) developed by Spaulding et al. (2010), which is a ratio of the Technical Challenge Index (TCI) to the Power Production Potential (PPP) of the energy extraction device. TCI is a measure of how difficult it is to site the device at a given location plus a measure of the distance to the closest electrical grid connection point. The PPP is an estimate of the annual power production of one of the devices. The site with the lowest TDI represents the optimum. This is the location with the lowest technical challenge as compared to the power production potential. The method can be applied to any offshore renewable energy type or extraction system once the technical attributes are specified.

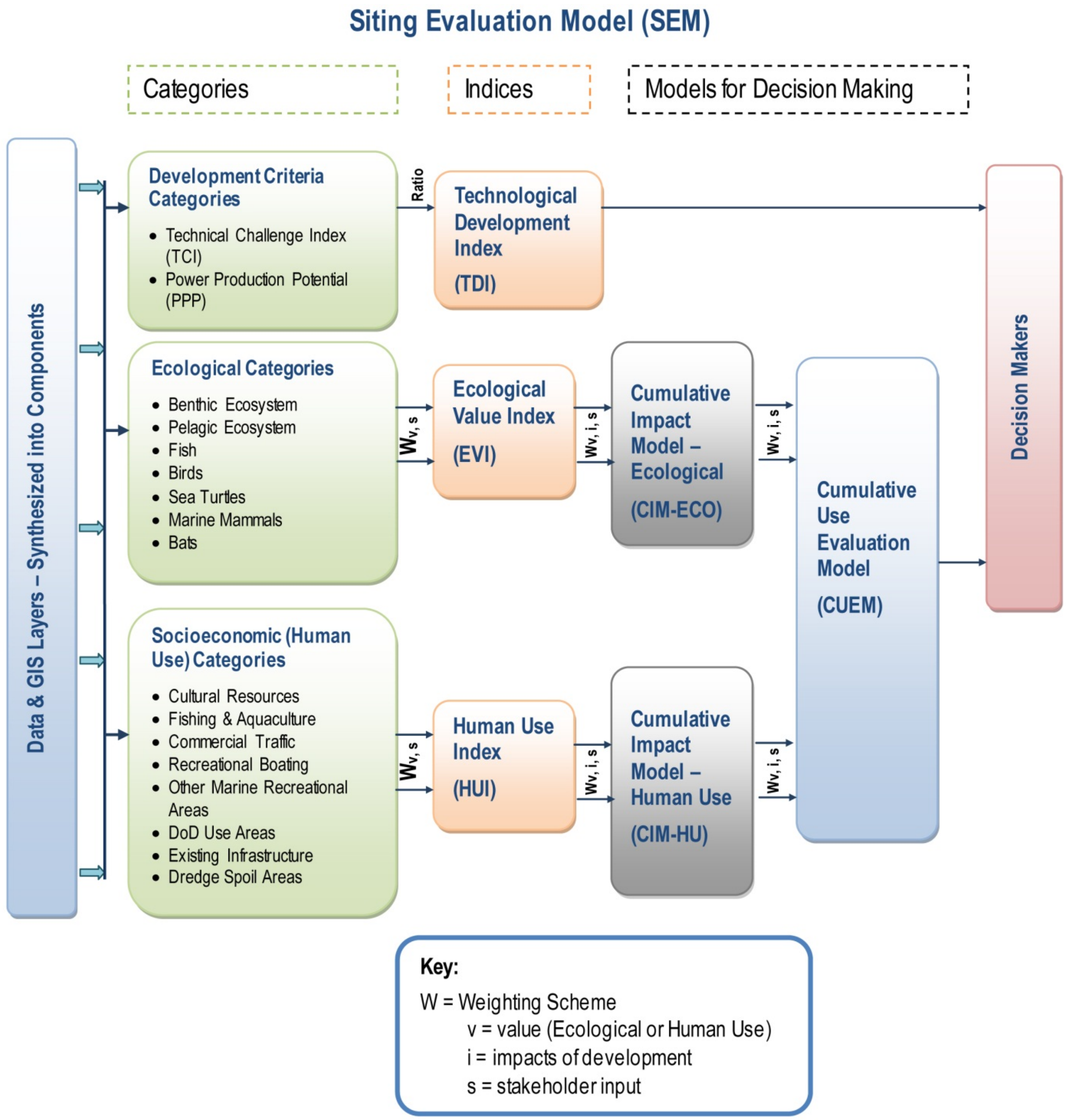


Figure 25. Framework for a Siting Evaluation Model for decision-makers, including indices of technological development potential, ecological value, and human use.

The decision maker can use the TDI in conjunction with the CUEM to inform the evaluation of the trade-offs between the development potential and the ecological value, socioeconomic value, and potential for impact of the area, as well as other issues and concerns pertinent to the decision-making process (such as stakeholder concerns and management priorities). Each of the indices can be overlaid, with weightings applied if desired, to identify potential conflicts and opportunities. The framework and SEM would easily be adapted as new technologies, environmental conditions and/or data needs develop, as the analysts and managers can adjust weighing factors appropriately.

The SEM was developed with a focus on ORE siting, but it could be used to evaluate any combination of competing uses of the offshore environment. For example, a decision-maker could use the framework to conduct a cumulative impact evaluation of an ORE development in addition to another type of development, such as an offshore liquefied natural gas (LNG) terminal, by including weightings for both of these projects in a single CUEM, or overlaying individual CUEMs created for each project. It could also be used to evaluate the potential impact of these two projects in conjunction with a variety of other proposed activities, such as changes to shipping lanes or placement of artificial reef materials. The framework allows for a cumulative impact evaluation to be conducted in a quantitative, scientifically-based manner that is open, transparent, flexible, and able to incorporate stakeholder and public input. Use of these tools could substantially enhance Federal, State, tribal, local, and regional decision-making and planning processes.

In addition to facility siting and cumulative impact analysis, various configurations of the EVI, HUI, CIM-Eco, CIM-HU, and CUEM indices could be used to inform coastal and marine spatial planning (CMSP) efforts. In 2010, President Obama signed an Executive Order establishing a National Policy for the Stewardship of the Ocean, Coasts, and Great Lakes and creating a National Ocean Council (NOC). This Executive Order adopts the Final Recommendations of the Interagency Ocean Policy Task Force, which prioritize the actions for the NOC to pursue. In these Final Recommendations, CMSP is identified as a national priority, and is described as follows:

> *"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."* (CEQ, 2010)

Consistent with the CMSP approach, the EVI and HUI indices consider the spatial distribution of all uses, resources, biological, and physical characteristics inside of a designated area. The CIM-Eco and CIM-HU indices go a step further by incorporating potential impacts of various activities on these uses/resources. Managers could use this information to enhance efficient use of the offshore environment, reduce environmental impacts, identify opportunities for shared use, and reduce use conflicts (both between different marine uses and between users and the environment).

5. CONCLUSIONS

The steps taken for this project were to: 1) Develop methods to design and test a new conceptual framework and approach for a cumulative environmental impact evaluation of offshore renewable energy development; 2) Outline an overall Siting Evaluation Model that considers both ecological values and socio-economic (human) uses; 3) Integrate various ecological data inputs into an Ecological Value Model considering multiple levels of organization, i.e., first into ecological components (e.g., individual species) and then ecological categories (e.g., birds, fish, benthic ecosystem); 4) Develop methods to quantify weighting factors and uncertainties for compositing ecological categories into an Ecological Value Index; and 5) Develop methods to quantify weighting factors and uncertainties for modifying the ecological category weights in the Ecological Value Index related to potential impacts of development in order to generate a Cumulative Impact Model (CIM-Eco), which would become part of the framework for the overall Siting Evaluation Model. The results of the CIM-Eco model may be combined with the results of a parallel human use model CIM-HU, which addresses the impacts of development on human uses of the marine environment. The CIM-HU is based on a Human Use Index would include weightings based on relative (human use) service values. Using these tools, a decision maker could evaluate the impacts of a development, and ideally, the topology of the composite index (including uncertainties) would identify areas most suitable for ORE development.

This report focuses on the development and methodology of the CIM-Eco component of the framework. Drawing from the biological valuation approach developed by Derous et al. (2007a,b,c), the approach for this project was to develop a model whereby input data (geospatial information describing the physical environment, ecosystems, fish and wildlife populations) can be integrated into a composite map of ecological value, with weighting factors that incorporate relative intrinsic and ecological values. At the species level, the input data are based on measures of aggregation: density, contribution to fitness, productivity, rarity, or uniqueness of attributes. Different criteria, such as the regional/global importance of local species can change the relative importance of the input layers to the model. Going a step further than Derous et al.'s (2007a,b,c) approach, we also applied additional weighting factors to address the relative potential impacts of ORE development, using the Offshore Renewable Energy Effects Matrix described in the Year 1 deliverable, "Task 1.2 Report on Monitoring the Potential Effects of Offshore Renewable Energy" as well as the "Effects Decision Tree" from the Task 1.5 Final Report.

Based on our experience in developing the CIM-Eco approach, as well as reviewing other marine spatial planning approaches, there are several challenges in applying ecological valuation as a useable tool for ORE siting. The most important factors influencing the results of the model are: (1) defining the appropriate scale for the valuation effort; (2) a lack of standardized input data; and (3) patchy or inconsistent data availability/coverage necessitating application of interpolation models or spreading algorithms with uncertain underlying assumptions.

Part of the difficulty with standardized input layers can be addressed by the use of a common ecological language. The NOPP project has adopted NOAA's CMECS in order to standardize all relevant data layers. Currently, CMECS addresses only the benthic environment (CMECS

Geoform, Substrate, and Biotic Components) and the pelagic environment (CMECS Water Column Component). The layers used to represent benthic and pelagic ecosystem components in this analysis (i.e., Scope for Growth index and the chlorophyll *a* concentration) can each be related to relevant CMECS components. If similar efforts are made when applying the CIM-Eco framework in other regions, data could be easily combined to enable very broad scale analyses or even regional comparisons.

Attaining comprehensive data with ample spatial coverage for ecological valuations can be difficult. Even within a well-studied area (e.g., the RI Ocean SAMP area), appropriate data sets can be limited. Marine spatial planning efforts generally require ecological valuation of broad-scale coastal zones, but in many cases, ecological data are typically highly variable, patchy, collected for another purpose, and/or focused on a particular area of concern. Data inputs are typically pulled from a variety of sources, and therefore include multiple studies, each with varying scopes, methodologies, and objectives. As a result, it can be challenging to standardize these data sets so that they can be combined in a meaningful way. Furthermore, data may simply not exist for particular ecosystem components, or may not have adequate spatial coverage. For example, for the benthic ecosystem only a subset of the RI Ocean SAMP area has been sampled for biological cover and densities, whereas an index of Scope for Growth was available for nearly the entire area of interest. In addition, we did not have sufficient spatial data to include bats in the present analysis, but bats could be a sensitive component in the RI Ocean SAMP area. The sampling coverage needed to truly represent broad-scale study areas is often unavailable and costly to obtain. This is particularly a problem for highly migratory species, which generally operate on broad spatial scales. However, even if data are not available for all resource categories of interest, applying the model with the data at hand may still be informative.

Modeling data layers based on spatial interpolations between points (as we did for the fish data in this study), or extrapolating a surface as a function of a variable with ample spatial coverage, has been used as one way to address the data gap problem (Degraer et al., 2008; EOEEA, 2009; Greene et al., 2010). However, as demonstrated by the bird surface-density models used in this study, the modeling method employed to generate a continuous topology can heavily influence the final results (see Section 2.3.1.2), and therefore warrants careful consideration. All statistical analyses operate under various sets of assumptions; not all data lend themselves to or can meet the specifics of these assumptions. Ecological data often fall into this category. Having a full understanding of each method's underlying operating assumptions and the limitations of the dataset(s) at hand is paramount to meaningful interpretation and use. Often, many of the assumptions associated with statistical analyses are violated, therefore compromising the overall use and interpretation of the results. Scientists and managers must be careful when applying these methods.

In view of the reality that data coverage and quality will vary by region and resource, and will rarely be sufficiently complete for spatial interpolation methods to provide reliable surfaces in all locations, we recommend that a hierarchy of approaches be developed for generating topologies, dependent on the nature, comprehensiveness, and uncertainties of the available data. The approaches may include various spatial statistical techniques (e.g., Kriging, Inverse-Distance Weighted Interpolation), empirical models, and behavioral models, depending on data availability and quality.

Determining the appropriate scale on which to analyze input data sets is another important element in ecological valuation efforts. As discussed in Section 2.3.1.1, the scale at which the data are analyzed will heavily influence the results, and therefore inappropriate scales can lead to skewed interpretation and poor decision making. For example, a non-migratory demersal fish species could most likely be assessed appropriately at a local scale, while some migratory species (e.g., large whales) should be assessed at a regional or coastal scale. Assessing a migratory species with a large geographic range at a local scale may lead to overestimation of the importance of the local area to that species.

Another limitation, but also a strength, of the model approach is the assignment of the weighting factors (i.e., valuation) to the input data, since alternative weighting schemes or relative rankings of individual layers could affect the final products considerably. The weighting schemes employed in this study are considered exploratory, and could be modified to integrate stakeholder input or other factors. Other weighting schemes may be discussed and evaluated in the future as issues and concerns arise. We envision the weightings to be used as a measure of the relative importance decision-makers might place on the various resources, and the views of various stakeholders, along with uncertainties, may be explored by varying the weightings. Thus, the weightings implicitly made in any trade-off decision-making process are explicitly stated using this framework, with a criteria-related basis, making the decision-making process transparent and documented.

A key challenge in siting an energy facility or other commercial or industrial project is balancing the needs of the diverse interests and resources that could be affected by the project while complying with regulatory standards and meeting project objectives. The SEM framework developed in this study provides a useful screening tool for initial ORE facility siting considerations, and is intended to be used and evaluated in conjunction with other environmental information, regulatory and management priorities, and stakeholder interests. The SEM was developed with a focus on ORE siting, but it could be used to evaluate any combination of competing uses of the offshore environment. For example, a decision-maker could use the framework to conduct a cumulative impact evaluation of an ORE development in addition to another type of development, such as an offshore LNG terminal, by including weightings for both of these projects in a single CUEM, or overlaying individual CUEMs created for each project. It could also be used to evaluate the potential impact of these two projects in conjunction with a variety of other proposed activities, such as changes to shipping lanes or placement of artificial reef materials.

The framework allows for a cumulative impact evaluation to be conducted in a quantitative, scientifically-based manner that is open, transparent, flexible, and able to incorporate stakeholder and public input. The approach may also be extended to other coastal and marine spatial planning efforts to enhance efficient use of the offshore environment, reduce environmental impacts, identify opportunities for shared use, and reduce use conflicts (both between different marine uses and between users and the environment). Use of these tools could substantially enhance Federal, State, tribal, local, and regional decision-making and planning processes.

LIST OF REFERENCES

Arnold, G.P. and B.H. Holford, 1995. A computer simulation model for predicting rates and scales of movement of demersal fish on the European continental shelf. ICES Journal of Marine Science 52: 981-990.

Brody, A., 1988. A simulation model for assessing the risk of oil spills to the California sea otter population and any analysis of the historical growth of the population. In: Population Status of California Sea Otters, , pp. 191–274. Siniff, D.B. and Ralls, K. (eds.), U.S. Department of the Interior, Minerals Management Service, Pacific Outer Continental Shelf Region, Los Angeles, CA. Contract 14–12–001–30033.

Brown, C.J., Smith, S.J., Lawton, P., Anderson, J.T., 2011. Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques. Estuarine, Coastal and Shelf Science 92: 502-520.

Council on Environmental Quality (CEQ). 2010. Final Recommendations of the Interagency Ocean Policy Task Force. July 19, 2010. http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf

Cryan, P.M. Research biologist, U.S. Geological Survey. Personal Communication. 2009.

Cryan, P.M., and Brown, A.C. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation 139: 1-11.

Degraer, S., Verfailie, E., Willems, W., Adriaens, E., Van Lanker, V. and Vincx, M. 2008. Habitat suitability modeling as a mapping tool for macrobenthic communities: an example from the Belgian part of the North Sea. Continental Shelf Research 28(3): 369-379.

De Groot, R.S., Wilson, M.A., and Boumans, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393–408.

Derous, S., Agardy, T., Hillewaert, H., Hostens, K., Jamieson, G., Lieberknecht, L., Mees, J., Mouleart, I., Olenin, S., Paelinckx, D., Rabaut, M., Rachor, E., Roff, J., Stienen, E.W.M., Van der Wal, J.T., Van Lancker, V., Verfaillie, E., Vincx, M., Weslawski, J.M., and Degraer, S. 2007a. A concept for biological valuation in the marine environment. Oceanologia 49(1): 99-128.

Derous, S., Verfaille, E., Van Lancker, V., Cortens, W., Steinen, E.W.M., Hostens, K., Mouleurt, I., Hillewaert, H., Mees, J., Deneust, K., Deckers, P., Cuvelier, D., Vincx, M., and Degraer, S. 2007b. A biological valuation map for the Belgian part of the North Sea: BWZee Final Report. Belgian Science Policy, Brussels, Belgium.

Derous, S., Austen, M., Claus, S., Daan, N., Dauvin, J.C., Deneudt, K., Depestele, J., Desroy, N., Heessen, H., Hostens, K., Husum Marboe, A., Lescrauwaet, A.K., Moreno, M.P., Mouleart, M., Rees, H., Ressurreicao, A., Roff, J., Talhadas Santos, P., Speybroeck, J., Stienen, E.W.M., Tatarek, A., Hofstede, R.T., Vincx, M., Zarzycki, T., and Degraer, S. 2007c. Building on the concept of marine biological valuation with respect to translating it to a practical protocol: Viewpoints derived from a joint ENCORA-MARBEF initiative. Oceanologia 49(4): 1-8.

ENCORA/MARBEF. 2006. Workshop on Marine Biological Valuation: Workshop Report. Ghent, Belgium.

Executive Office of Energy and Environmental Affairs (EOEEA), Commonwealth of Massachusetts. 2009. Volume 2: Development of an Ecological Valuation Index for the Massachusetts Ocean Management Plan. Draft Massachusetts Ocean Management Plan (MOP), Boston, MA.

Federal Geographic Data Committee (FGDC), 2012. Coastal and Marine Ecological Classification Standard, Version 4.0, January 2012. Standards Working Group, FGDC. http://www.csc.noaa.gov/benthic/cmecs/CMECS_Version%20_4_Final_for_FGDC.pdf.

Fisheries and Ocean Canada (DFO). 2005. Identification of ecologically and biologically sensitive areas. Ecosystem Status Report 2004/006, DFO Canada Science Advisory Section, Ottawa, Ontario, Canada.

Ford, R.G., J.A. Wiens, D. Heinemann, and G.L. Hunt, 1982. Modelling the sensitivity of colonially breeding marine birds to oil spills: guillemot and kittiwake populations on the Pribilof Islands, Bering Sea. Journal of Applied Ecology 19:1-31.

Freeman, A.M., III. 1993. The measurement of environmental and resource values: Theory and methods. Resources for the Future, Washington, DC.

French, D.P. and M. Reed, 1990. Potential impact of entanglement in marine debris on the population dynamics of the northern fur seal, *Callorhinus ursinus*. p. 431-452 In: R.S. Shomura and M.L. Godfrey (eds.) Proceedings of the Second International Conference on Marine Debris, April 2 7, 1989, Honolulu, Hawaii.

French, D.P., M. Reed, J. Calambokidis and J. Cubbage, 1989. A simulation model of seasonal migration and daily movements of the northern fur seal, *Callorhinus ursinus*. Ecological Modelling 48:193 219.

Graham, J.H. and Duda, J.J. 2011. The humpbacked species richness-curve: A contingent rule for community ecology. International Journal of Ecology, 2011 (868426) 15pp.

Greene, J.K., Anderson, M.G., Odell, J., and Steinberg, N. (eds.). 2010. The Northwest Atlantic Marine Ecoregional Assessment: Species, Habitats and Ecosystems. Phase One. The Nature Conservancy, Eastern U.S. Division, Boston, MA.

Jayko, K., M. Reed and A. Bowles, 1990. Simulation of interactions between migrating whales and potential oil spills. Environmental Pollution 63:97 127.

Kopp, R.J., and Smith, V.K. 1993. Valuing natural assets: The economics of natural resource damage assessment. Resources for the Future, Washington, D.C.

Kostylev, V.E., Hannah, C.G., 2007. Process-driven characterization and mapping of seabed habitats, in: Todd, B.J., Greene, H.G. (Eds.), Mapping the seafloor for habitat characterization: Geological Association of Canada. Geological Association of Canada, pp. 171-184.

National Oceanic and Atmospheric Administration (NOAA). 1992. Report of the NOAA Panel on Contingent Valuation. Damage Assessment and Restoration Program, US Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD.

NOAA. 1995. Habitat equivalency analysis: an overview. Damage Assessment and Restoration Program, US Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD.

Nunes, P.A.L.D., and van den Bergh, J.C.J.M. 2001. Economic valuation of biodiversity: sense or nonsense? Ecological Economics 39: 203-222.

Paton, P., K. Winiarski, C. Trocki, and S. McWilliams, 2010. Spatial distribution, abundance, and flight ecology of birds in nearshore and offshore waters of Rhode Island. Interim Technical Report for the Rhode Island Ocean Special Area Management Plan, University of Rhode Island, Kingston, RI.

Reed, M., Jayko, K., Bowles, A., Anderson, E., Leatherwood, S., and Spaulding, M. 1987a. Computer simulation of the probability that endangered whales will interact with oil spills. Final Report to U.S. Department of Interior Minerals Management Service, Alaska Region, Anchorage. Contract No. 14-12-0001- 30076. 182 pp. plus appendices.

Reed, M., D.P. French, J. Calambokidis and J. Cubbage, 1987b. Simulation modelling of the effects of oil spills on population dynamics of northern fur seals, OCS MMS 86 0045, Final Report to U.S. Department of Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK, Contract No. 14 12 0001 30145, 158 p.

Reed, M., Jayko, K., Bowles, A. and Leatherwood, S. 1988. Numerical models of bowhead and gray whale migration in Alaskan waters. Ecological Modelling 44: 1-42.

Reed, M., D.P. French, J. Calambokidis and J. Cubbage, 1989. Simulation modelling of the effects of oil spills on population dynamics of northern fur seals, Ecological Modelling 49:49 71.

Shumchenia, E.J., Grilli, A., King, J.W., Spaulding, M. 2012. Scope for Growth and Disturbance Data for the RI Ocean SAMP Area. Unpublished Data.

Smith, V.K. 1996. Estimating Economic Values for Nature: Methods for Non-market Valuation. Edward Elgar, Cheltenham, UK.

Smith, P. G. R. and Theberge, J. B. 1987. Evaluating natural areas using multiple criteria: theory and practice. Environmental Management 11(4): 447-460.

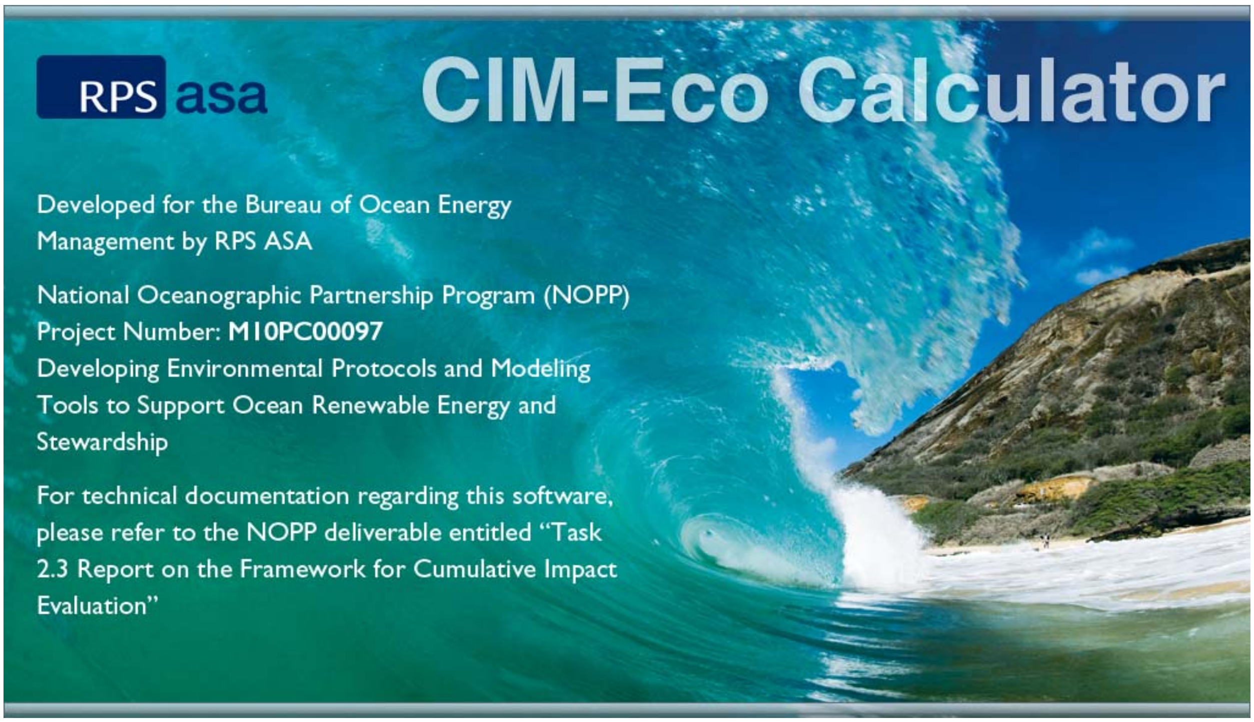
Spalding , M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdana, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., and Roberson, J. 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. BioScience 57(7): 573-583.

Spaulding, M.L., Grilli, A., and Damon, C., and Fugate, G. 2010. Application of Technology Development Index and principal component analysis and cluster methods to ocean renewable energy facility siting. Marine Technology Society Journal 44(1): 8-23.

Unsworth, R.E., and Bishop, R.C. 1994. Assessing natural resource damages using environmental annuities. Ecological Economics 11(1): 35-41.

Van Gelder, R.G., and Wingate, D.B. 1961. The taxonomy and status of bats in Bermuda. American Museum Novitates 2029: 1-9.

Appendix A
CIM-Eco Calculator User Guide



June 2012

Table of Contents

Figures

1 ABOUT THE CIM-ECO CALCULATOR

1.1 Background

The Cumulative Impact Model-Ecological (CIM-Eco) Calculator was developed by RPS ASA as part of the National Oceanographic Partnership Program (NOPP) Project Number: M10PC00097: Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship, funded by the Bureau of Ocean Energy Management (BOEM).

The steps taken for this project were to 1) Develop methods to design and test a new conceptual framework and approach for a cumulative environmental impact evaluation of offshore renewable energy (ORE) development; 2) Outline an overall Siting Evaluation Model (SEM) that considers both ecological values and socio-economic (human) uses; 3) Integrate various ecological data inputs into an Ecological Value Model (EVM) considering multiple levels of organization, i.e., first into ecological components (e.g., individual species) and then ecological categories (e.g., birds, fish, benthic ecosystem); 4) Develop methods to quantify weighting factors and uncertainties for compositing ecological categories into an Ecological Value Index (EVI); and 5) Develop methods to quantify weighting factors and uncertainties for modifying the ecological category weights in the EVI related to potential impacts of development in order to generate a Cumulative Impact Model (CIM-Eco), which would become part of the framework for the overall SEM (Figure 1-1). The results of the CIM-Eco model may be combined with the results of a parallel human use model, CIM-HU, which addresses the impacts of development on human uses of the marine environment. The CIM-HU is based on a Human Use Index (HUI) that would include weightings based on relative (human use) service values. The CIM-Eco and CIM-HU indices form the basis of a Cumulative Use Evaluation Model (CUEM). Using these tools, a decision maker could evaluate the impacts of a development, and ideally, the topology of the composite index (including uncertainties) would identify areas most suitable for offshore renewable development (or other offshore activities).

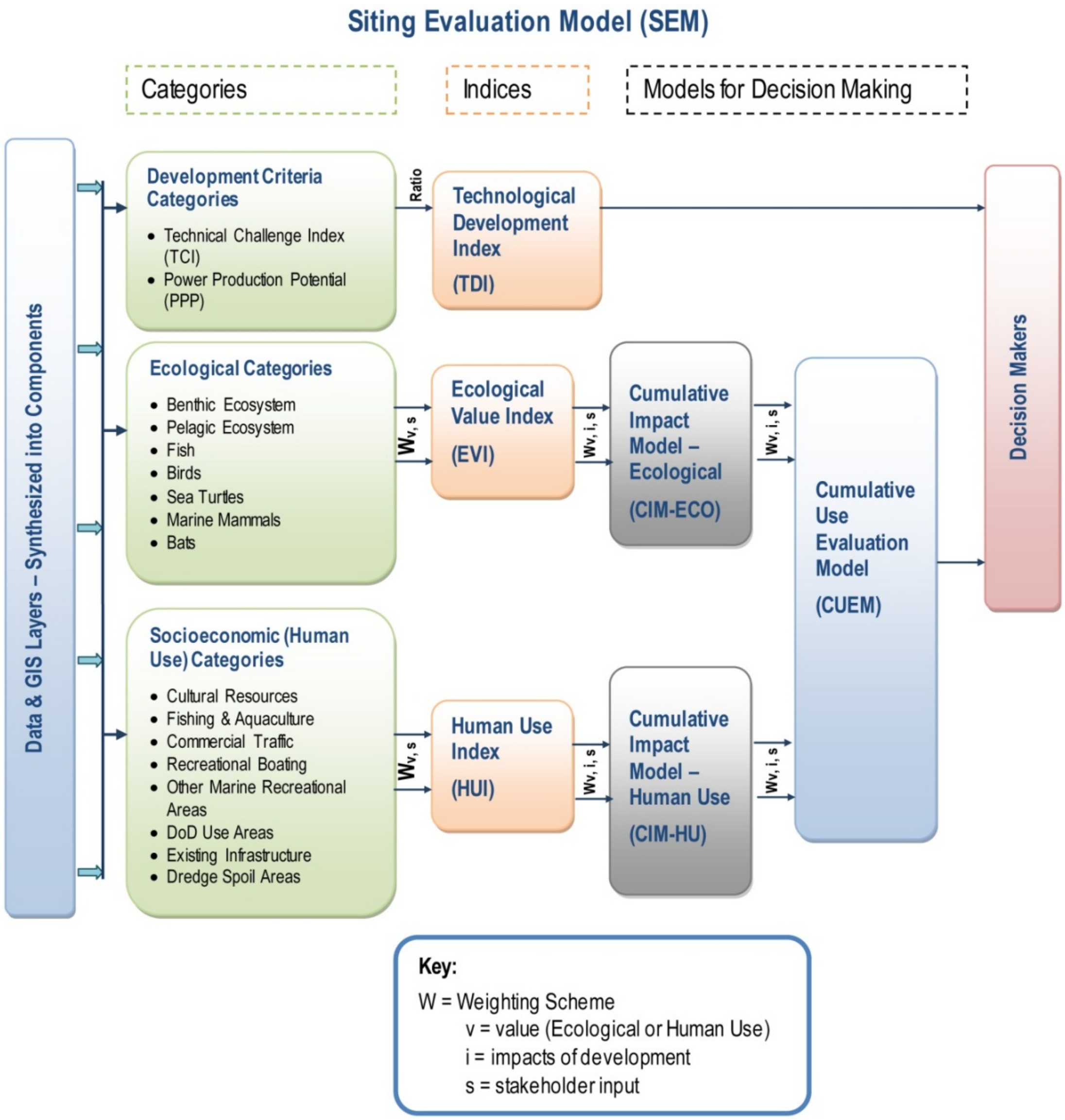


Figure 1-1 Framework for a Siting Evaluation Model for decision-makers, including indices of technological development potential, ecological value, and human use

The CIM-Eco portion of the Siting Evaluation Model is generated by the application of two intermediate products, category-level EVMs, and a composite EVI. First, ecological data inputs representing various components (e.g., individual species) are integrated into a series of category-level EVMs (e.g., birds) using a variety of weighting factors. The EVMs are then summed in to an EVI. Weighting factors quantifying the potential impacts of ORE development are used to modify the ecological category weights in the EVI in order to generate the CIM-Eco index. One of the strengths of this approach is that the weightings implicitly made in any trade-off decision-making process are explicitly stated with a criteria-related basis, making the decision-making process transparent and documented.

The CIM-Eco Calculator is a simple tool that allows the user (e.g., developers, regulators) to easily carry out the calculations of the CIM-Eco portion of the SEM framework and manipulate the weighting schemes to examine cumulative impacts. Using the CIM-Eco Calculator, all user groups would be able to explore the data and implications at all levels, from input data layers to category EVM, composite EVI, and CIM-Eco maps. These maps may be printed, saved as images, or imported into a GIS system for further analysis and display.

The CIM-Eco Calculator is pre-loaded with data for the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP) area, but the tool can be applied to any geographic area. It currently includes a framework that can evaluate ecological categories for fish/invertebrates, birds, bats, marine mammals, sea turtles, and pelagic and benthic ecosystem components. A filename key for the RI Ocean SAMP data is provided in Section 9.

For additional information about the model framework and technical approach, please refer to the main report, entitled “Task 2.3 Report on the Framework for Cumulative Impact Evaluation.”

1.2 System Requirements

The CIM-Eco Calculator is compatible with PC machines running Windows XP Service Pack 3 or Windows 7.

When running the CIM-Eco Calculator for the first time, this error may appear if the computer’s .NET framework is outdated:

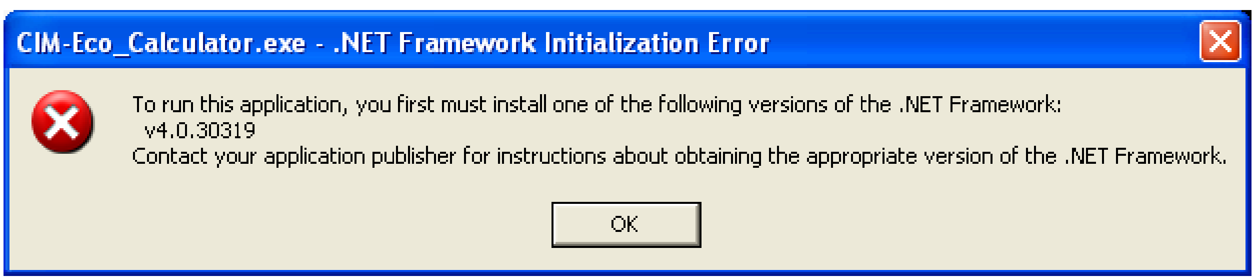


Figure 1-2 .NET Framework Initialization Error

To correct this issue, download the version 4 .NET framework from the following website:

http://www.microsoft.com/en-us/download/details.aspx?id=17851

After installing the .NET framework, re-launch the CIM-Eco Calculator.

2 CIM-ECO DATA PREPARATION

To use the CIM-Eco Calculator to evaluate new projects, data must be compiled, normalized, and filed in the prescribed folder structure.

Each geographic location needs to have the folder structure depicted in Figure 2-1. The root folder (e.g., RHODE ISLAND) should have the following folders: **BASEMAP**, **IMAGE**, **INPUT**, **OUTPUT**, **SCENARIO**; and a **location.config** file. A blank location (i.e., WORLD) is provided which includes a world-wide basemap and the blank folder structure.

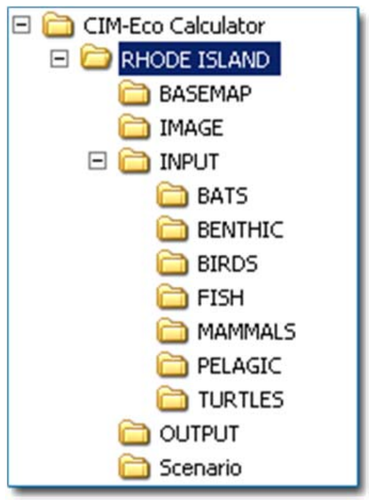


Figure 2-1 Folder Structure

To start a new location, copy the entirety of "WORLD" and rename to your preferred location name. Then, either proceed using the provided basemap, or delete it and copy in your own basemap into the **BASEMAP** folder. Please note that the base map must be in an ESRI ArcMap Shapefile format.

All input data will be stored in the folder structure within **INPUT**. The resource categories that are currently evaluated in the CIM-Eco Calculator are **BATS**, **BENTHIC**, **BIRDS**, **FISH**, **MAMMALS**, **PELAGIC**, and **TURTLES**. All data for the ecological categories will need to be compiled in a standard ASCII grid format. All grids need to have exactly the same number of rows, columns, origin, cell size, and no data value. ASCII grids are easily created in programs such as ESRI ArcMap. Data will also need to be normalized to a 0-1 scale in order for the composite and index calculations to report correctly. For further information, please see the description of data inputs in the main report.

The **IMAGE**, **OUTPUT**, and **SCENARIO** folders can be left blank. They are automatically populated as you work within the CIM-Eco Calculator program. The types of files found within each are described in the following sections.

To add more data, or further explore the RI Ocean SAMP data provided in the RHODE ISLAND geographic location folder, any additional grids added will need to exactly match the properties of the existing ASCII input grids. The ASCII properties for the RI Ocean SAMP ASCII input files are listed below.

RI Ocean SAMP ASCII Grid Properties:

ncols	1583
nrows	915
xllcorner	-71.894318243778
yllcorner	40.876684786223
cellsize	0.00068395007087239
NODATA_value	-9999

3 GETTING STARTED

To start using the CIM-Eco Calculator, begin by copying the **CIM-Eco Calculator** folder from the CD to the desired location on your computer. To open the program, double-click on the **.exe** file.

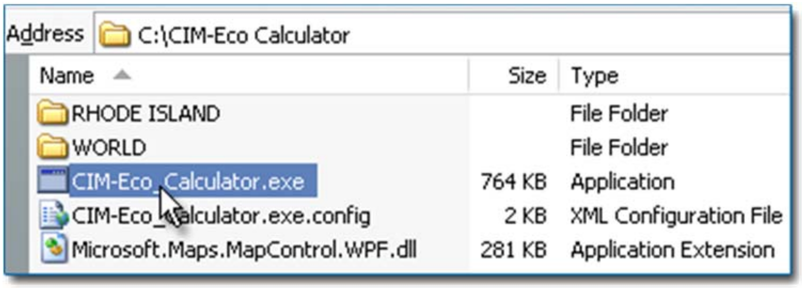


Figure 3-1 Starting the Application

The first time the application is run, the user is asked to select the root folder (e.g., C:\CIM-Eco Calculator). If the wrong root folder is inadvertently selected, it can be reset by closing the application, then re-opening the application while holding down the **Ctrl** key.

The root folder contains geographic location folders. A geographic location consists of an area defined by its outermost longitude and latitude coordinates. All data and model output are stored within this location. Each location folder contains the folder structure necessary to hold the data inputs.

Figure 3-2 Select Root Folder

Figure 1-2 displays the folder structure within the RHODE ISLAND location. All locations must have this folder structure. A template is provided called WORLD that users can copy and rename to create a new location.

If the root folder contains more than one location, the user can select the location from the **File** menu button, hover over **Locations** and click the location of choice. If a new location folder is created while the CIM-Eco Calculator program is open, the user will need to close and reopen the program before the new location will appear in this list.

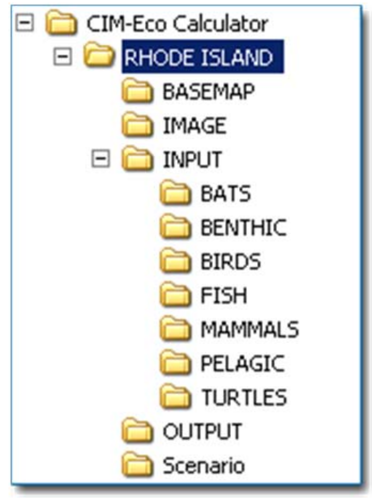


Figure 3-3 Folder Structure

4 CREATING A NEW ECOLOGICAL SCENARIO

To begin a new Ecological Scenario, click on the **File** menu button, hover over the **New** option and click **Ecological Scenario**.

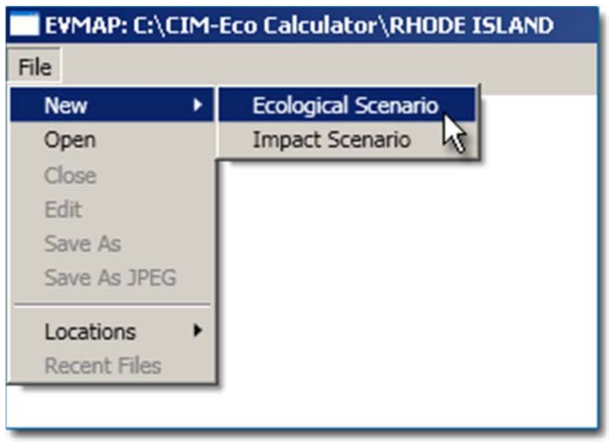


Figure 4-1 New Ecological Scenario

4.1 Ecological Weighting

The first thing to appear is the **Ecological Weighting** window (Figure 4-2). Here, users can add data files to populate the different ecological categories, apply weightings, and then carry out the processing. Click on the different tabs to access the different ecological categories.

Figure 4-2 Ecological Weighting window for inputting data layers and weightings

4.1.1 Add Files

Figure 4-3 displays what occurs after clicking on the **Add Files** button. Since the user had the **Fish** tab selected in the Ecological Weighting window, the file browser opens to the **FISH** folder and lists its contents. Select one or multiple **.asc** files to load into the Ecological Weighting window.

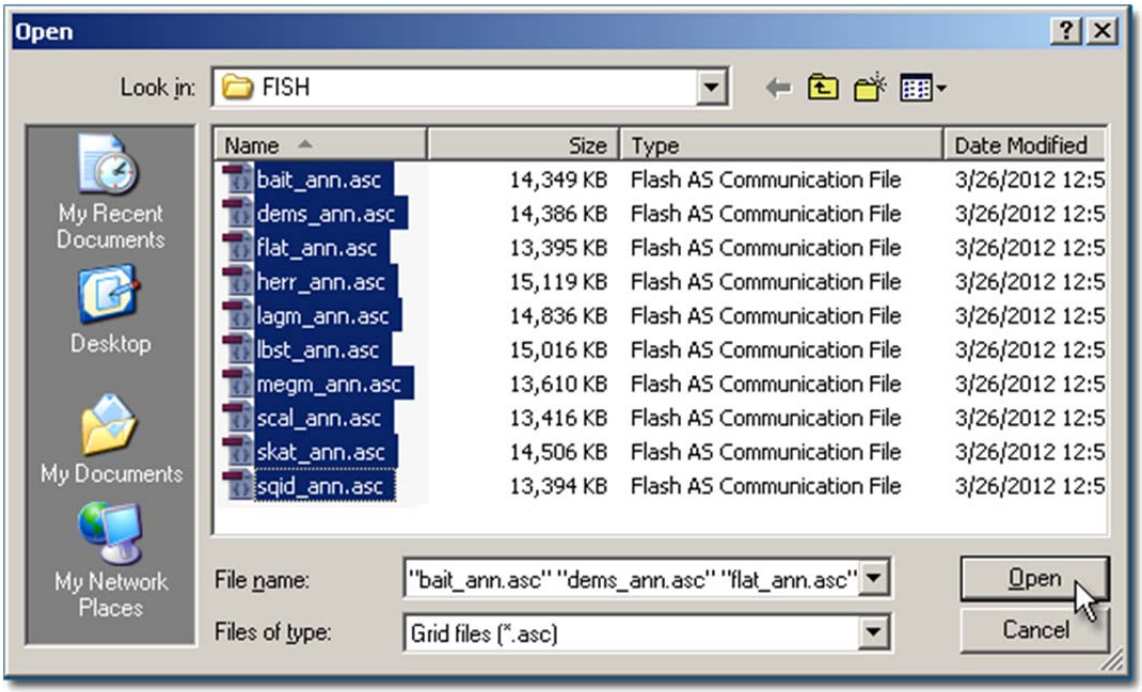


Figure 4-3 Add Files

Figure 4-4 displays the **Ecological Weighting** window after files have been added. Click the '**X**' next to the filename to remove the layer or '   ' to replace it. Click inside the textboxes in order to change the different weightings for each file. For guidance on the weightings, click the **Help** button or refer to the Task 2.3 Report on the Framework for Cumulative Impact Evaluation.

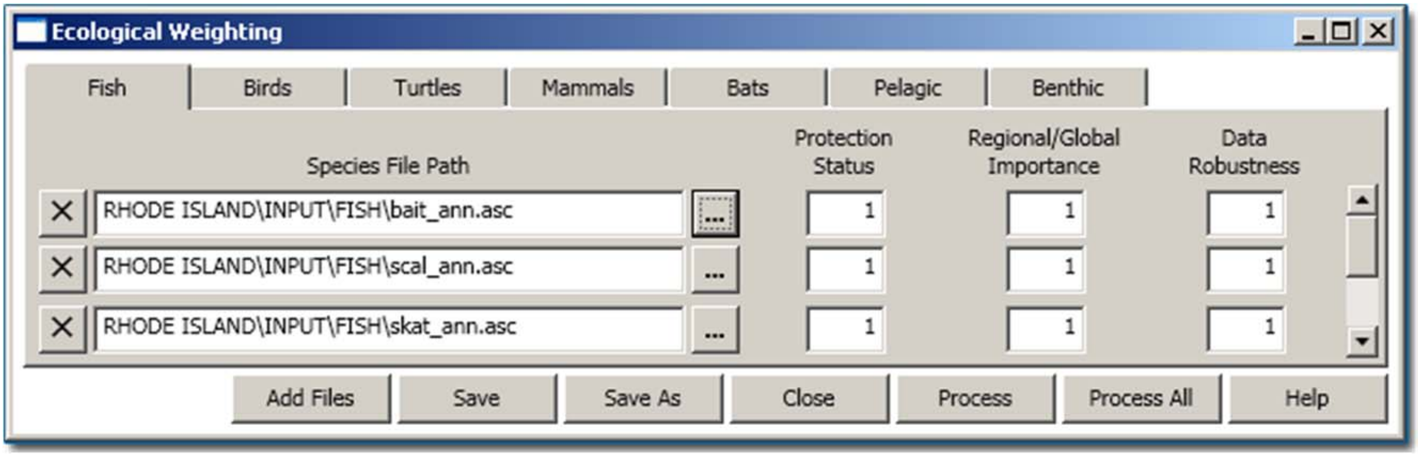


Figure 4-4 Ecological Weighting (Fish Data)

Figure 4-5 displays the **Ecological Weighting** window after the user navigated to the **Pelagic** tab and added a file. For guidance on the weightings, click the **Help** button or refer to the Task 2.3 Report on the Framework for Cumulative Impact Evaluation.

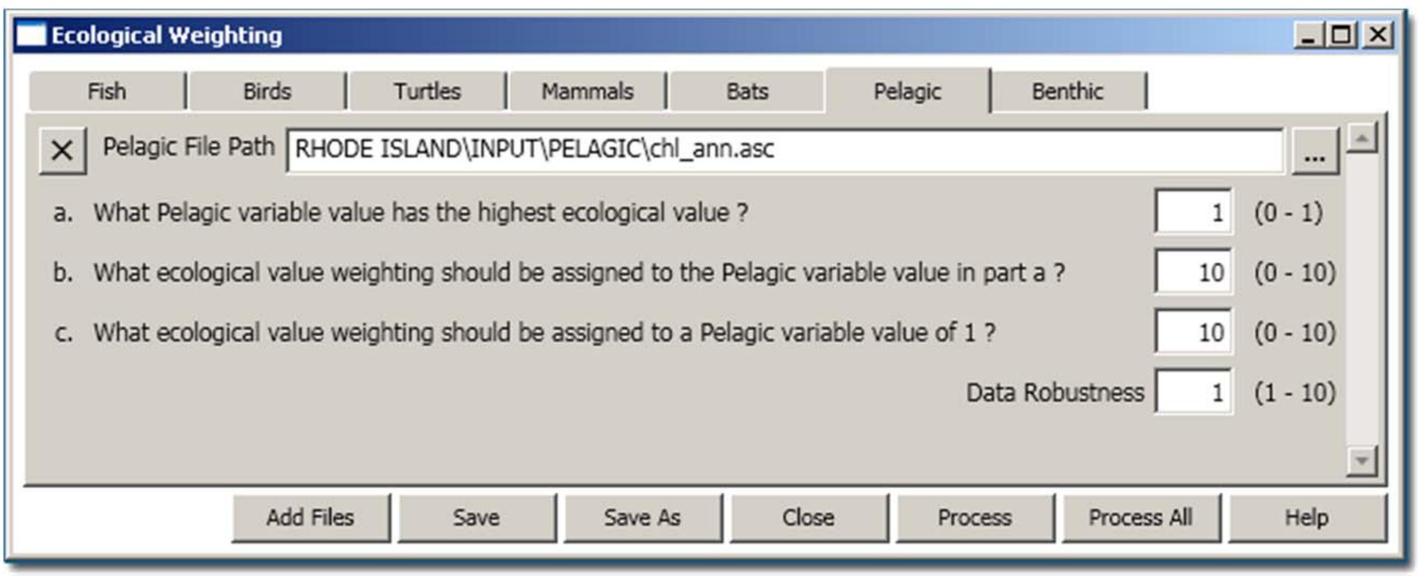


Figure 4-5 Ecological Weighting (Pelagic)

4.1.2 Save

To save your current progress, click the **Save** button to open the **Save As** window (Figure 4-6). Ecological scenario files are saved with the **.eco** file extension in the **SCENARIO** folder.

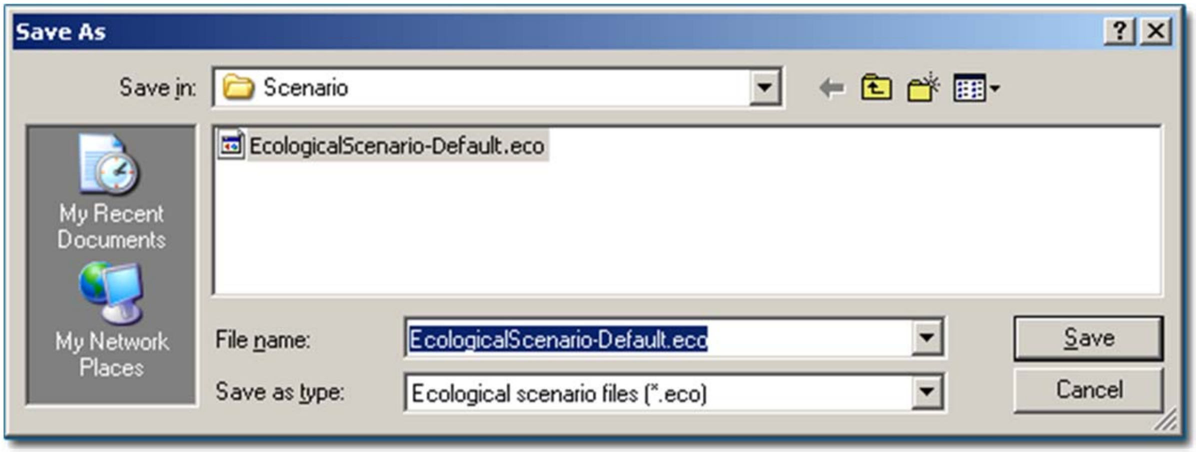


Figure 4-6 Save As (Ecological Scenario)

4.1.3 Save As

The **Save As** option will save the scenario on which the user is currently working. This feature can be used to make a copy of an existing Ecological Scenario and save it as a different filename.

4.1.4 Process / Process All

Click the **Process All** button to process all entered files or the **Process** button to process only the files associated with whichever tab (e.g., fish) the user currently has highlighted.

Figure 4-7 displays the **Ecological Weighting** window after the **Process** button has been clicked. Click the **Cancel** button to stop the processing.

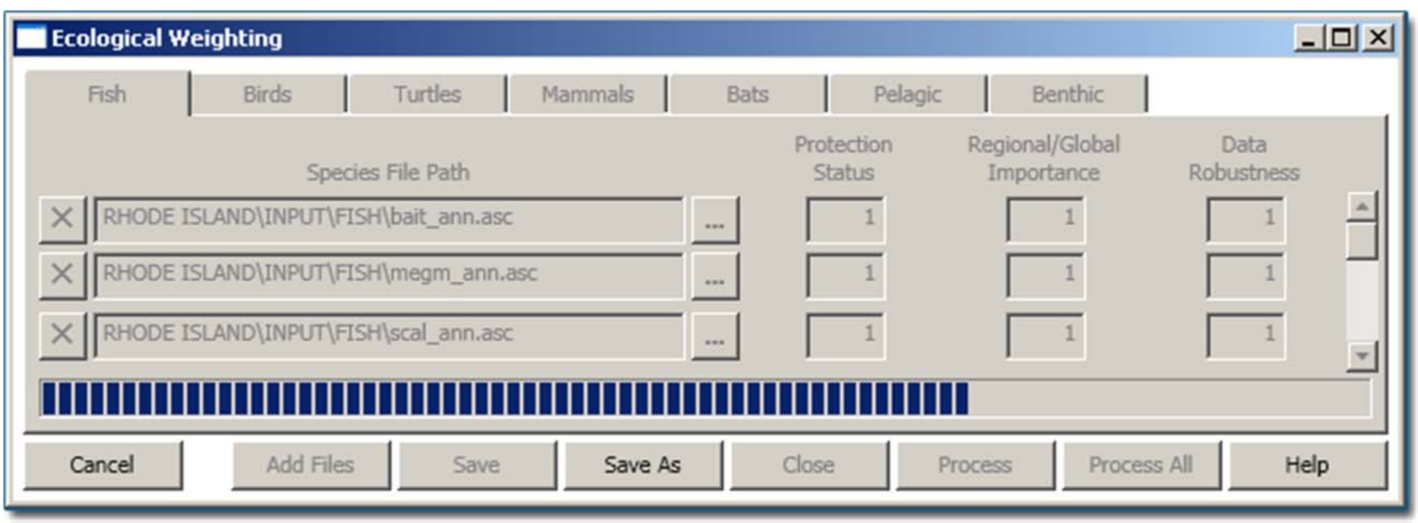


Figure 4-7 Ecological Weighting (Processing)

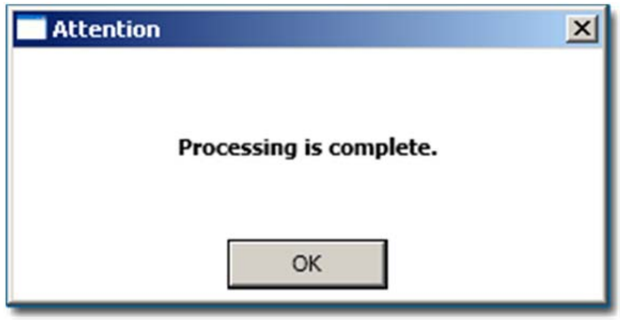


Figure 4-8 Processing Complete Notification

Once processing has completed, click the **Close** button to view the graphical results in the map viewer. The resulting processed category EVMs and composite EVI ASCII grids can be found in the **OUTPUT** folder. All files are labeled with the scenario name and appended with the category name. If desired, these files can be imported into ESRI ArcMap for further analysis.

To return to the Ecological Scenario window for an existing scenario, select **Edit** from the **File** menu. Once there, the user can add or remove files or change the values for the different weightings. Once finished, click the **Process** or **Process All** button and then **Close** to return to the map.

5 CREATING A NEW IMPACT SCENARIO

An Impact Scenario can be created only if the user already has a processed Ecological Scenario stored. To get started, click on the **File** menu button, hover over the **New** option and click **Impact Scenario**.

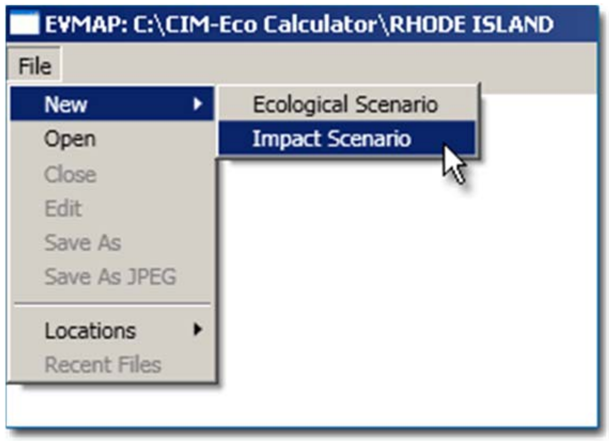


Figure 5-1 New Impact Scenario

5.1 Impact Weighting

The first thing to appear is the **Impact Weighting** window (Figure 5-2). Here, users select an existing Ecological Scenario file (extension **.eco**) and apply various impact weightings to the different ecological categories. Browse and select the **.eco** file by clicking the ‘ ’ button. Click and drag sliders to change the impact weighting applied to each category.

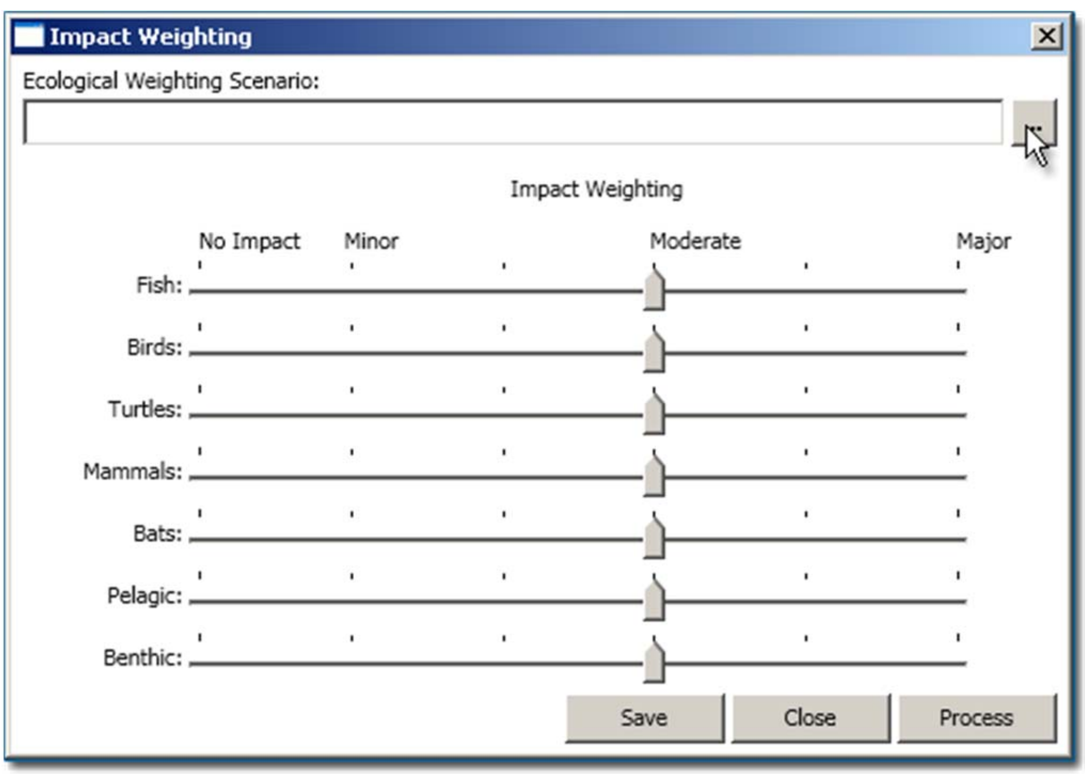


Figure 5-2 Impact Weighting

Once an Ecological Scenario has been added and impact weightings are set, click the **Process** button. The user will be first prompted to save the Impact Scenario and then processing will begin. A notification will be generated once processing has finished and the resulting ASCII file can be found in the **OUTPUT** folder. Click the **Close** button to view the graphical results in the map viewer.

To return to the Impact Scenario window for an existing scenario, select **Edit** from the **File** menu. Once there, the user can add or remove files or change the impact weightings. Once finished, click the **Process** button and then **Close** to return to the map.

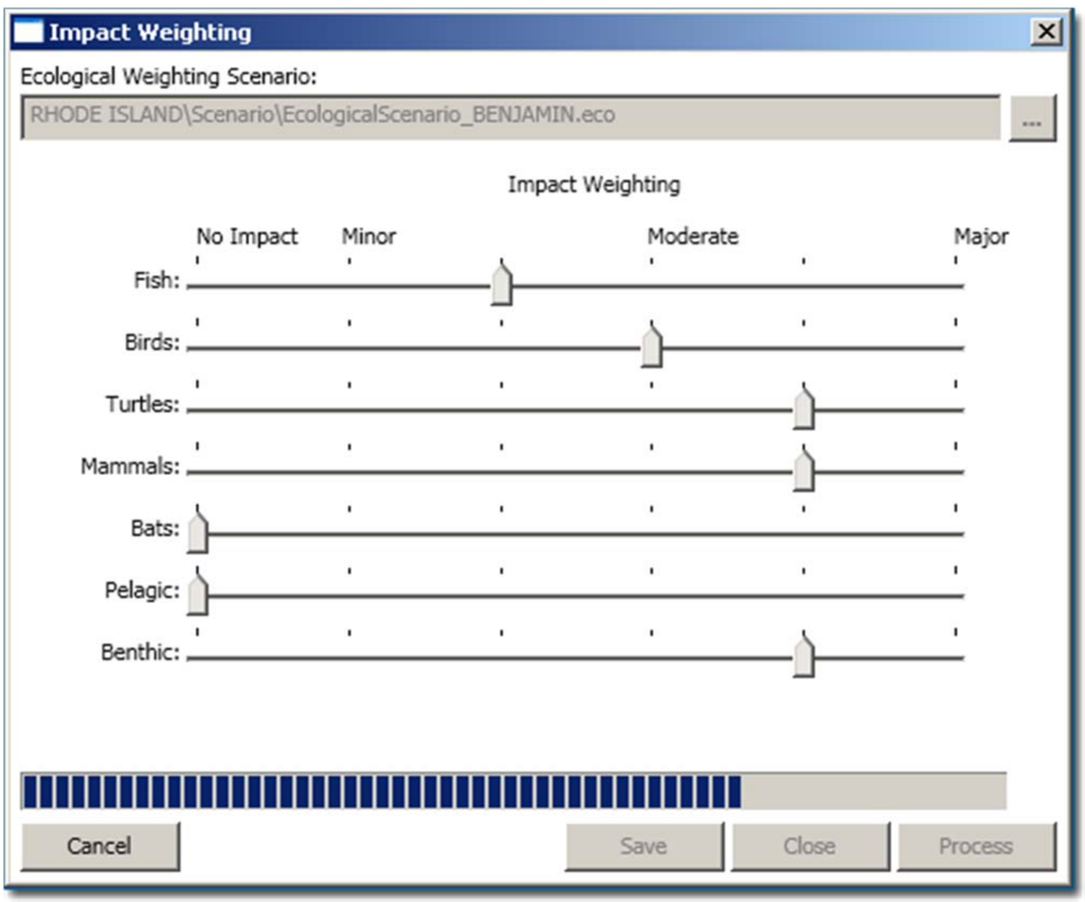


Figure 5-3 Impact Weighting (Processing)

6 OPENING AN EXISTING SCENARIO

To open an existing processed scenario, click on the **File** menu button and click the **Open** option.

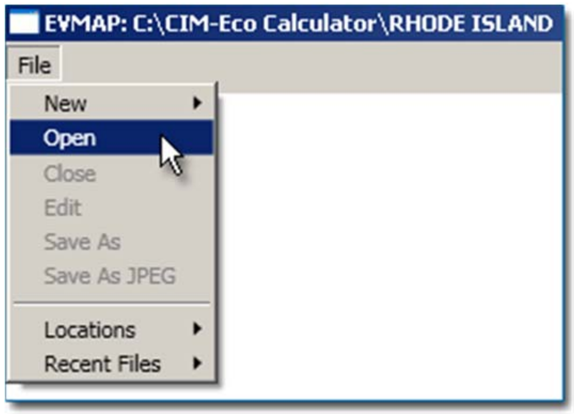


Figure 6-1 Open Scenario

The **Open** window displays the contents of the **Scenario** sub-folder of whichever location the user has chosen. Figure 6-2 displays the **.eco** and **.imp** files located in the **Scenario** folder for the RHODE ISLAND location. The scenarios used to generate the figures for the Task 2.3 Report are provided for the user as examples (i.e., “EcologicalScenario-Default.eco”; “ImpactScenario-AMI.imp”; and “ImpactScenario-block-island.imp”).

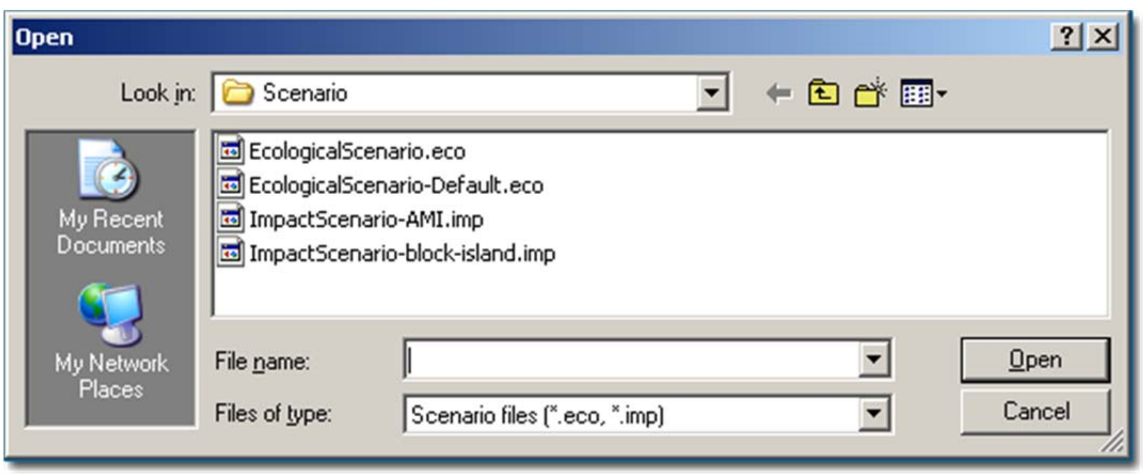


Figure 6-2 .eco and .imp Files in Scenario Folder

Once the scenario is opened, click on the **File** menu button and click the **Edit** option (Figure 6-3) to open the Ecological or Impact Scenario window in order to view/edit the weightings values.

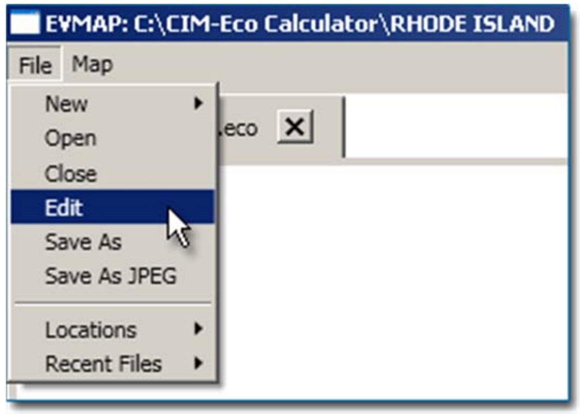


Figure 6-3 Edit an Existing Scenario

7 MAP

7.1 Navigation

There are several ways to navigate the map.

7.1.1 Zoom

Zoom in, out, or to output by clicking on the **Map** menu. **Zoom to Output** zooms the viewing window to the extent of grid that has been processed.

In addition, the user can double-click on the map to zoom in. If the mouse has a scroll-wheel, rolling it forward/backward will zoom in/zoom out.

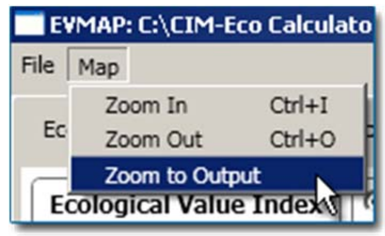


Figure 7-1 Map Menu

7.1.2 Pan

To pan across the map, position the mouse over the map, click and hold the left mouse button and drag the map.

7.2 Results Filter for Ecological Scenario

When viewing an Ecological Scenario, the user has the ability to view the various results layers by clicking the corresponding radio button in the filter list located in the upper-left corner of the screen. The **Composite** filter option (Figure 7-3) displays the composite EVI, which is comprised of all the category EVMs (Figure 7-2). If a category is greyed-out (e.g., “Bats” in the figures below), this indicates that there was no input data selected for that category.

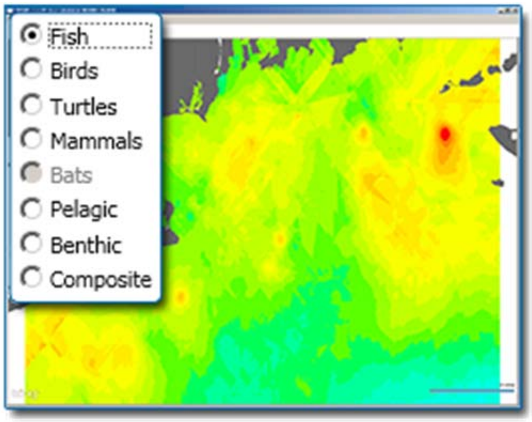


Figure 7-2 Results Filter (Fish)

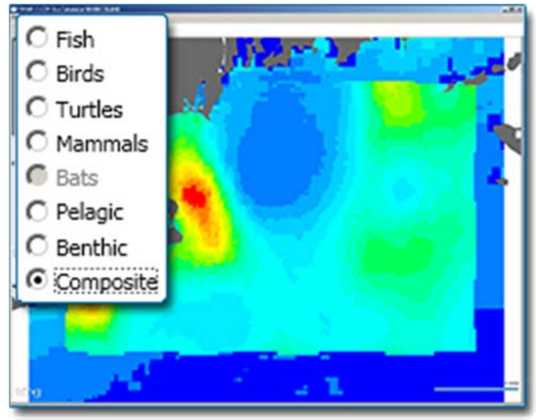


Figure 7-3 Results Filter (Composite)

7.3 Ecological Value Index / CIM-Eco Index

Also located in the upper-left corner of the map screen is a legend that displays the resulting values for each layer, called the **Ecological Value Index** (if viewing an ecological scenario) or the **CIM-Eco Index** (if viewing an impact scenario). These indices assign a color to different value ranges and are then displayed on the map.

7.3.1 Changing the Number of Colors

To change the number of colors displayed, click and drag the bottom of the panel. The minimum number of colors to display is 2; the maximum is 20.

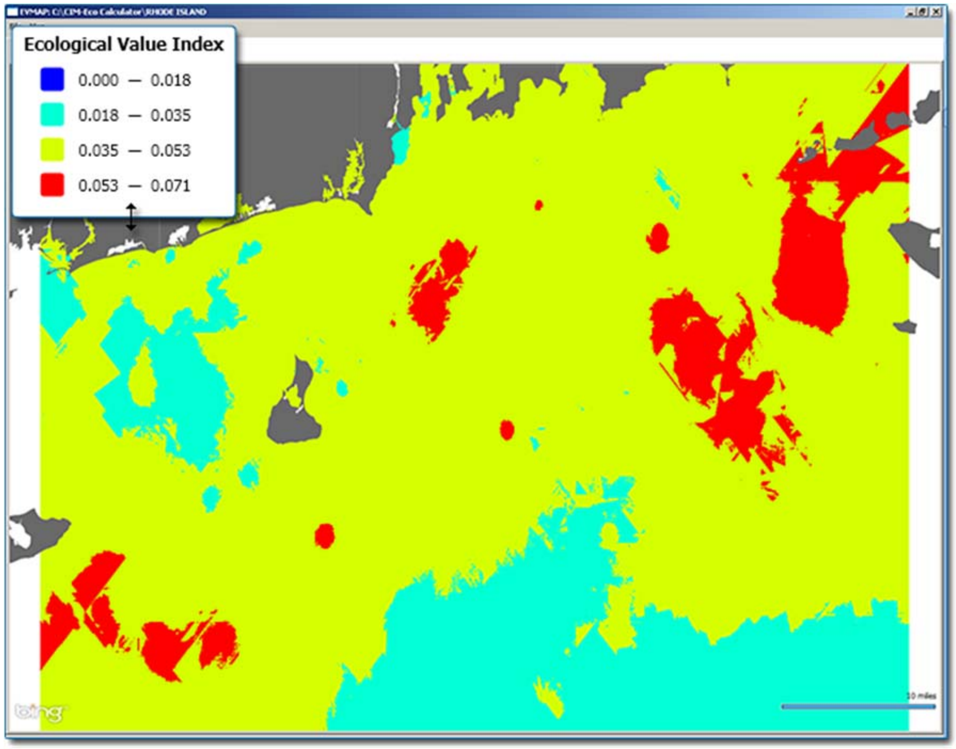


Figure 7-4 Ecological Value Index (4 colors)

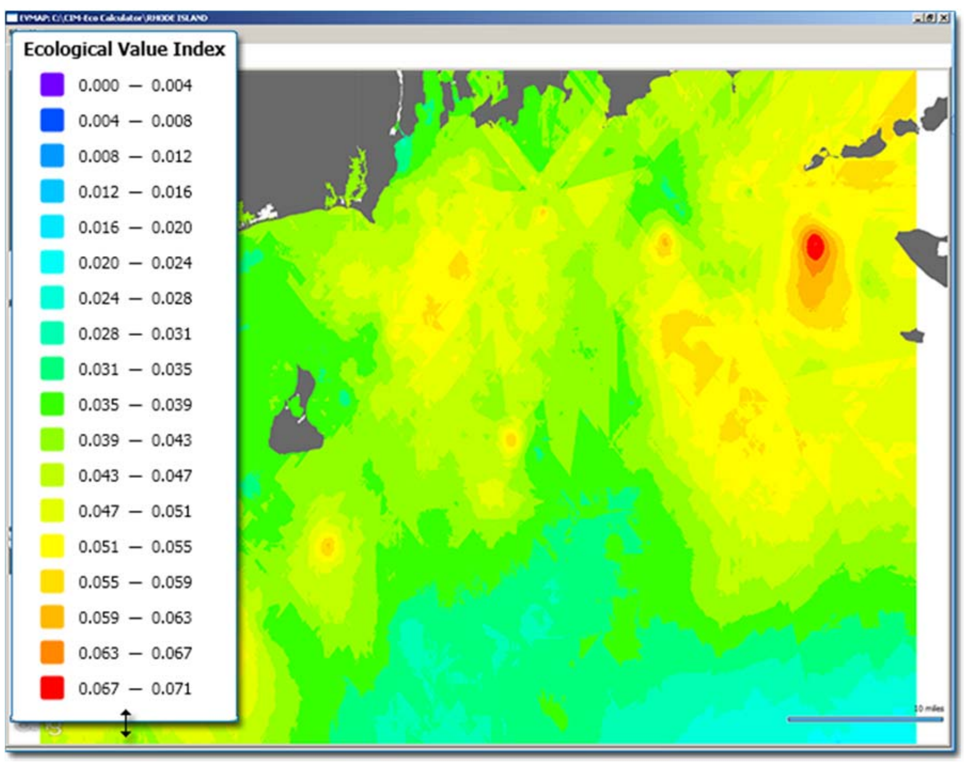


Figure 7-5 Ecological Value Index (18 colors)

7.3.2 Changing the First/Last Colors

Click on the first and/or last color box to display a color palette. Then, click on any color to make the change. For additional flexibility in generating map figures for reports or other documents, we recommend importing the results ASCII files (from the **OUTPUT** folder) into ESRI ArcMap.

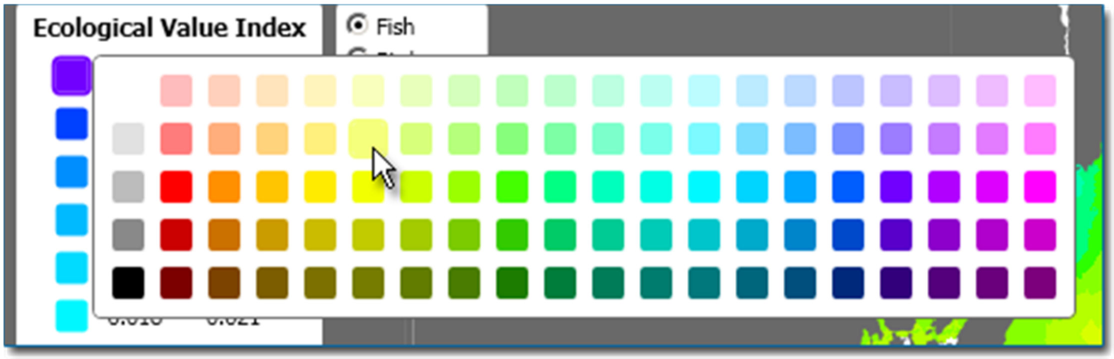


Figure 7-6 Color Palette

7.3.3 Information Panel

Located beneath the list of colors and associated ranges, is a panel that displays the X/Y coordinates of the mouse (according to the grid) as well as the current index value at that point.

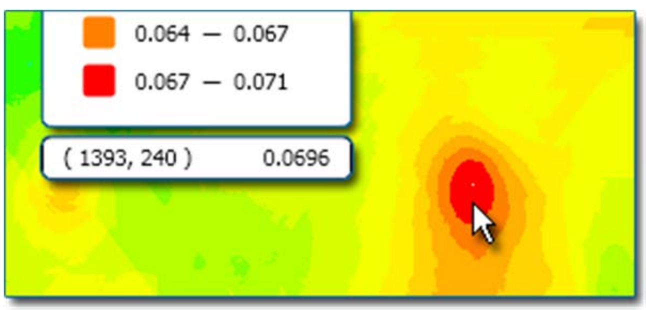


Figure 7-7 Information Panel

8 FILE MENU

Located in the upper-left corner of the application, the **File** Menu offers a number of options when viewing an Ecological or Impact Scenario.

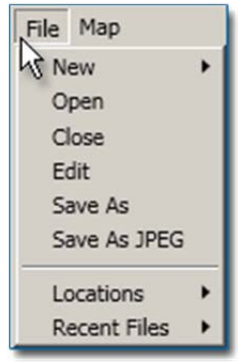


Figure 8-1 File Menu

8.1.1 New / Open

A new tab will appear at the top of the screen when an existing Ecological/Impact Scenario is opened or a new one is created. Simply click on the corresponding tabs to return to switch between the different scenarios that are currently open.

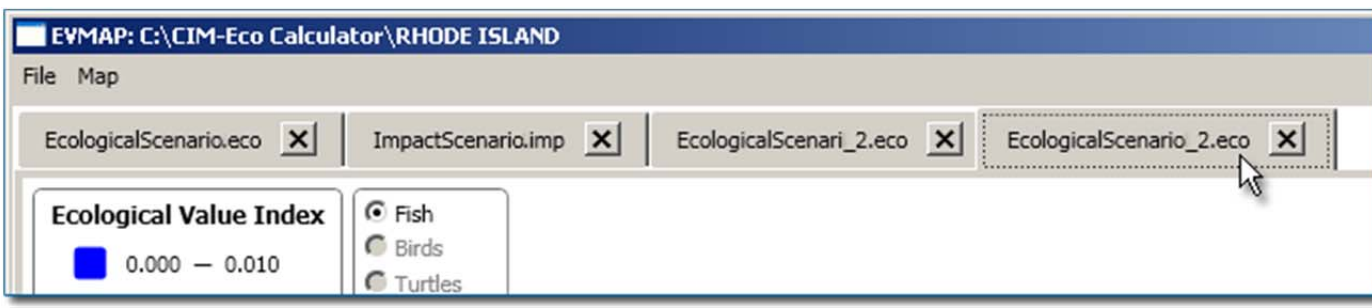


Figure 8-2 Multiple Tabs

In addition to Ecological and Impact Scenarios, the user has the ability to open and view the input ASCII grid files (**.asc**) located within the subfolders under the **INPUT** folder. Navigate to one of these folders, click on the **Files of type** drop-down list and select **Grid files (*.asc)** in order to see the list of files. Like the Ecological and Impact Scenarios, the grid file will open in a new tab.

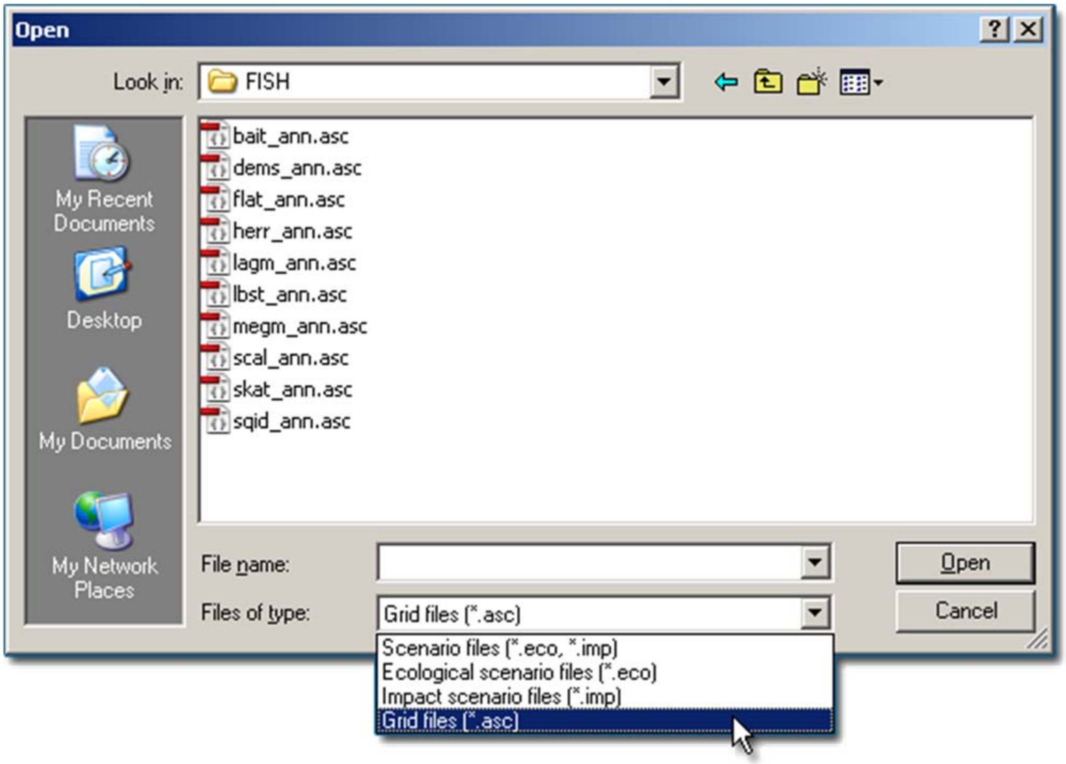


Figure 8-3 Opening an ASCII Grid File

8.1.2 Edit

The **Edit** option will go back to the Ecological or Impact Weighting screen (depending on which scenario the user currently has open). Once there, the user can add or remove files or change the values for the different weightings. Once finished, click the **Process** or **Process All** button and then **Close** to return to the map.

8.1.3 Save As JPEG

The **Save As** option will save the scenario on which the user is currently working. Clicking on the **Save As JPEG** option will save a JPEG image of the current scenario and save it to the **IMAGE** folder in the corresponding location folder.

8.1.4 Locations

By hovering over the **Locations** option, the user will be able to see all of the available location folders. Click on a different location to switch.

9 RI OCEAN SAMP FILENAME KEY

A filename key is provided below for the RI Ocean SAMP data input layers provided with the CIM-Eco Calculator. For a detailed description of these data input layers, refer to Appendix B of the Task 2.3 Report on the Framework for Cumulative Impact Evaluation.

Benthic
Scgrwth_grid.asc: Scope for Growth index.

Pelagic
Chl_ann.asc: Annual average surface chlorophyll a concentration, represented as percent of the seasonal maximum value.

Fish
All layers in this category are annual averages, represented as percent of the seasonal maximum value.

Bait_ann.asc: Baitfish abundance
Dems_ann.asc: Demersal fish abundance
Flat_ann.asc: Flatfish abundance
Herr_ann.asc: River herring and smelt abundance
Lagm_ann.asc: Large gamefish abundance
Lbst_ann.asc: Lobster abundance
Megm_ann.asc: Medium gamefish
Scal_ann.asc: Sea scallop abundance
Skat_ann.asc: Skate abundance
Sqid_ann.asc: Squid abundance

Birds
All layers in this category are annual averages, represented as percent of the seasonal maximum value.

Alcd_ann.asc: Alcid abundance
Cdck_ann.asc: Seaduck abundance
Gull_ann.asc: Gull abundance
Loon_ann.asc: Loon abundance
Noga_ann.asc: Gannet abundance
Shwt_ann.asc: Shearwater abundance
Tern_ann.asc: Tern abundance
Wisp_ann.asc: Petrel abundance

Sea Turtles
All layers in this category are annual averages, represented as percent of the seasonal maximum value.

Letu_ann.asc: Leatherback sea turtle sightings per unit effort (SPUE)
Lotu_ann.asc: Loggerhead sea turtle SPUE

Marine Mammals
All layers in this category are annual averages, represented as percent of the seasonal maximum value.

Bodo_ann.asc: Common bottlenose dolphin SPUE
Fiwh_ann.asc: Fin whale SPUE
Hapo_ann.asc: Harbor porpoise SPUE
Huwh_ann.asc: Humpback whale SPUE
Miwh_ann.asc: Minke whale SPUE
Piwh_ann.asc: Pilot whale SPUE
Riwh_ann.asc: North Atlantic right whale SPUE
Sado_ann.asc: Short-beaked common dolphin SPUE
Seal_ann.asc: Seal SPUE
Spwh_ann.asc: Sperm whale SPUE
Wsdo_ann.asc: Atlantic white-sided dolphin SPUE

APPENDIX B

DESCRIPTION OF RI OCEAN SAMP DATA INPUTS USED FOR THE CIM-ECO EXAMPLE

TABLE OF CONTENTS

1.0 INTRODUCTION

To illustrate the application of the ecological Cumulative Impact Model (CIM-Eco), the framework was applied to data compiled for the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP) project. Spatial data were collected from several historical Rhode Island data sets and from ongoing RI Ocean SAMP research projects. The collection effort involved processing (transfer, compilation, standardization, and gridding) of geospatial data on the benthic ecosystem, the pelagic ecosystem, fish, birds, sea turtles, and marine mammals.

The geospatial data sets (layers) for the region of concern, typically in a Geographical Information System (GIS) format, were processed to a first level of components that capture and summarize the important ecological attributes (such as species density at certain times of the year). These data were gridded (i.e., put in raster format) in an approximately 78-m by 59-m resolution grid identical to that used for the Technology Development Index (TDI) analysis (Spaulding et al., 2010). The data grid has an origin at 40.88°N, 71.89°W, with cell sizes of 0.0007 degrees in both longitude and latitude.

In order to compare across ecological resources, each input grid had to be normalized. This procedure was completed in ArcGIS 9.3 where the annual maximum raw value (e.g. abundance, sightings per unit effort, etc.) for each component was used to scale the seasonal values. Annual means were calculated by summing the seasonal components and dividing by the total seasons sampled.

2.0 INPUT DATA

2.1 BENTHIC ECOSYSTEM

The benthic ecosystem is difficult to classify in the offshore environment due to sporadic sampling and varying community compositions. Indices are often used to generally characterize locations. The index employed here is Shumchenia et al.'s (unpublished data) Scope for Growth (SG), following the methods of Kostylev and Hannah (2007). This index combines physical and biological components of the water column and near bottom conditions to describe the potential for production in the benthos. To calculate SG, all of these indices were combined in a linear additive model, where each variable received equal weight. The final SG index is gridded at 500 m cell size (Figure 1).The equation used is:

$$SG = \frac{FA+TM-TA-TI+O}{5},$$

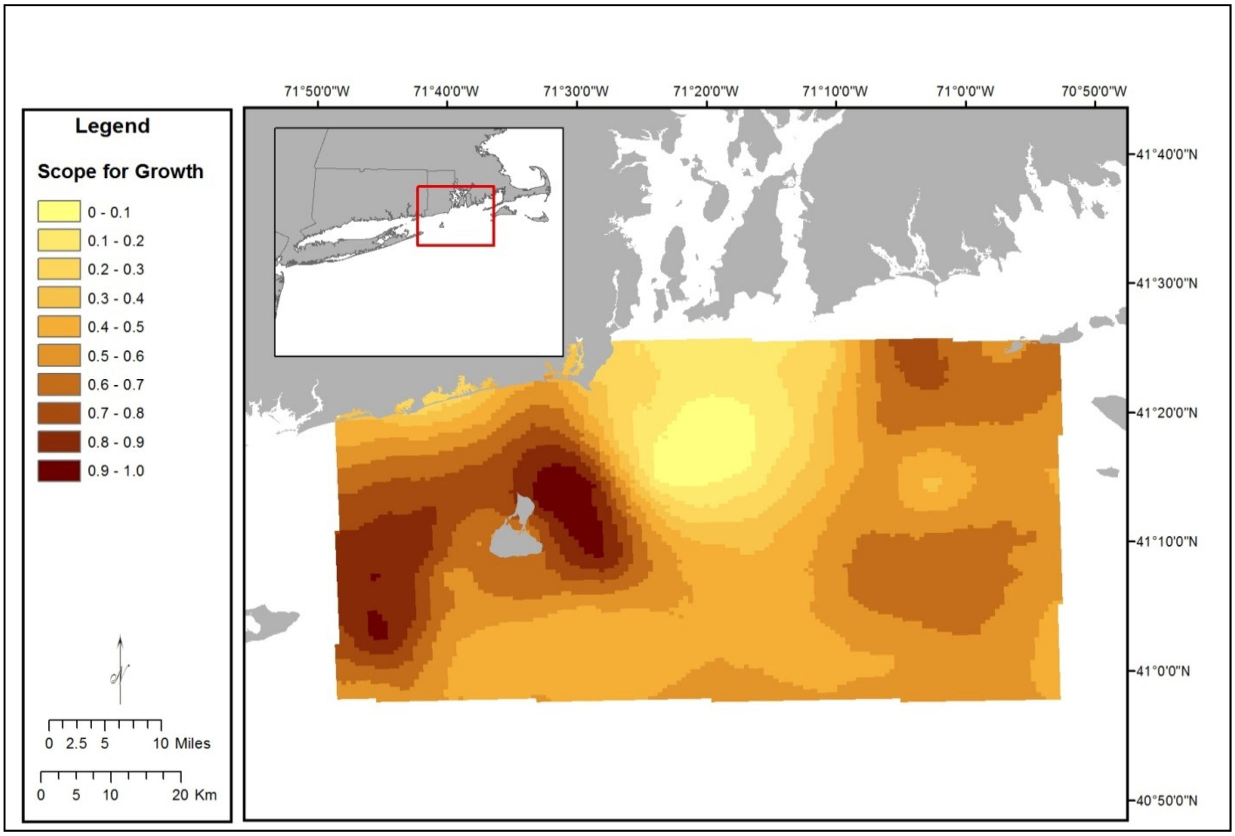
where *FA* = food availability, *TM* = annual mean bottom temperature (TM), *TA* = annual range in bottom temperature, *TI* = inter-annual root mean square (RMS) of bottom temperature, and *O* = near-bottom oxygen saturation. These variables are described below.

A Food Availability (*FA*) Index was calculated by taking the log of the ratio of chlorophyll *a* concentration to water depth and then subtracting the stratification index, as an estimate of benthic-pelagic coupling. The resulting index was scaled from 0 to 1. Chlorophyll *a* data are from monthly Sea Viewing Wide Field-of-View Sensor (SeaWiFS) data interpreted by Hyde (2010), for the years 1998-2007. The October 10-year mean (1998-2007) value was chosen for this study because it appeared to best reflect the annual maximum chlorophyll *a* concentration for this dataset. This is in contrast with the data utilized by Kostylev and Hannah (2007), which were chosen to reflect spring blooms since no spring blooms were evident in the Rhode Island data. These data were interpolated to an 80 m grid in order to match the resolution of the NOAA bathymetry dataset.

For stratification, Codiga and Ullman (2010) provided sigma-t values at 10 depth intervals at 210 sites throughout the RI Ocean SAMP area. The surface value was subtracted from the bottom value to calculate stratification at every site for each season (spring, summer, fall, winter). The annual mean stratification was calculated for each site and these values were normalized on a scale of 0 to 1 to create a stratification index. These data were interpolated to a 500 m grid using Ordinary Kriging.

Codiga and Ullman (2010) provided near-bottom temperature values at 210 sites throughout the SAMP area for each season. From these, the annual mean bottom temperature (*TM*), the annual range in bottom temperature (TA) and the inter-annual RMS of bottom temperature (*TI*) were calculated. Each of these variables was normalized on a scale of 0 to 1 and interpolated to a 500 m grid using Ordinary Kriging.

Near-bottom oxygen saturation (*O*) data were provided by Codiga and Ullman (2010) from a ship-based survey conducted in September 2009. The September data were chosen in order to capture the season minimum values of oxygen saturation. In the future, this layer may be re-modeled in order to incorporate an annual mean value. The data from these 45 observations across the SAMP area were normalized on a scale of 0 to 1 and interpolated to a 500 m grid using Ordinary Kriging.



FFigure 1. Gridded Scope for Growth Index.

2.2 Pelagic Environment

The plankton-based pelagic community is enhanced by higher phytoplankton production rates, drawing fish and wildlife predators to the area. Thus, the ecological value of pelagic ecosystem is indexed to phytoplankton productivity. The Nature Conservancy, as part of their Northwestern Atlantic Marine Ecoregional Assessment, compiled chlorophyll *a* data from the Sea Viewing Wide Field-of-View Sensor (SeaWiFS) satellite images. Data from January 1998 to December 2006 were collected and monthly data were averaged into seasonal representations (see Figure 2 for an annual average of these data). These image data have a spatial resolution on the order of 1.1 km^2. For more information on these data, refer to http://www.nature.org/ourinitiatives/regions/northamerica/areas/easternusmarine/index.htm.

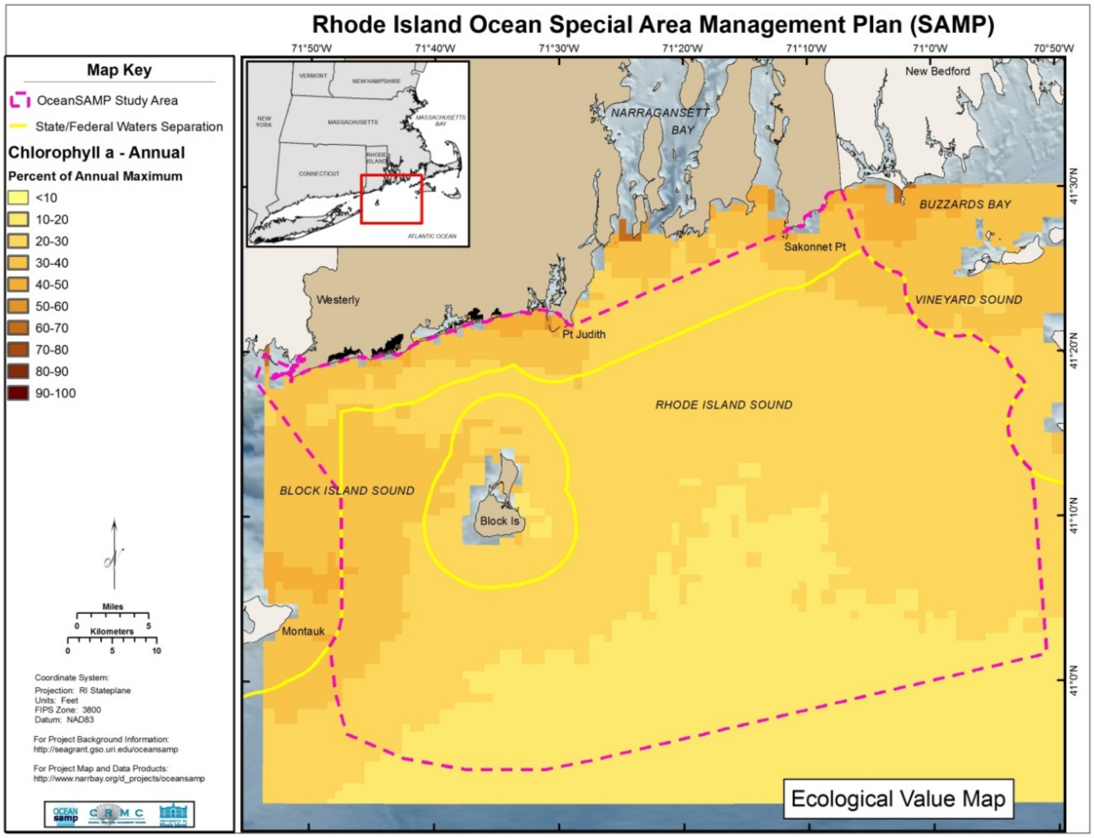


Figure 2. Annual surface chlorophyll *a* concentration, represented as percent of the maximum annual value.

2.3 Fish and Large Invertebrates

Fish resources data were compiled from several sources, as there is no one fisheries-independent survey or dataset that provides abundance and biomass information for the entire RI Ocean SAMP area. The data from four different fishery-independent bottom trawl surveys conducted by the Rhode Island Department of Environmental Management (RIDEM), URI Graduate School of Oceanography (GSO), Northeast Area Monitoring and Assessment Program (NEAMAP), and the National Marine Fisheries Service (NMFS) were compiled for the years 1999 to 2008. These data were standardized, aggregated, and analyzed by Bohaboy et al. (2010) to provide a baseline characterization of abundance and biomass for the RI Ocean SAMP area (Figure 3). This baseline characterization focused on 22 finfish, shellfish, and crustacean species (Table 3).

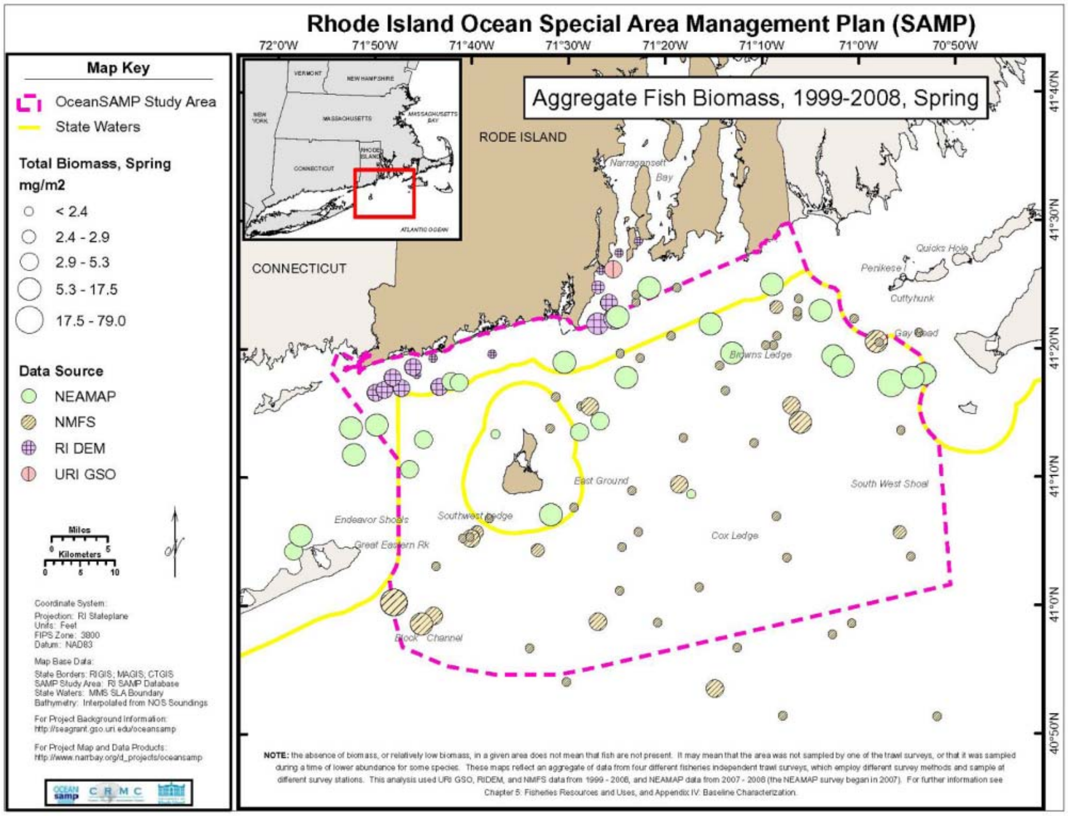


Figure 3. Aggregate Fish Biomass, 1999-2008, Spring (Bohaboy et al. 2010, Figure 37 therein).

Bottom trawl surveys are appropriate for sampling demersal and some pelagic species, but they may not accurately characterize the occurrence of some pelagics, shellfish, and crustaceans. As a result, although an important component of fish resources, the migration pathways and seasonal abundance trends of large pelagic teleosts (e.g., tuna) and elasmobranchs (e.g., large sharks), were not included in the baseline characterization. Moreover, bottom trawls are not able to survey certain bottom types/habitats like moraines, rocky areas, or areas with other obstructions. Therefore, the baseline characterization likely underestimates the abundance of species associated with these bottom types/habitats. The baseline characterization reflects a synthesis of data from the four different fisheries-independent trawl surveys, each with differences in the vessel types, gear types, and methods used. Analysis of the biomass data revealed that survey effects were the second most important factor in accounting for variation in total biomass. As a result, the biomass estimates for the individual surveys are not directly comparable and cannot simply be combined into a composite map. In order to correct for survey effects and compile the data, the survey effect coefficients from the multi-way ANOVA conducted by Bohaboy et al. (2010) were obtained and used to adjust the raw biomass data. This method is a simple approach to correcting for survey effects, and has inherent limitations and assumptions. For example, this approach assumes that catchability of each species was equal within a given survey. In reality, survey catchability is on a species-by-species basis. Despite the limitations, this was the most reasonable approach given the scarcity of data for certain species and our need to compile the data from the different surveys into a single composite map.

After correcting for survey effects, in order to be incorporated into the framework, the trawl survey point data were converted into a standardized surface of relative density using Kriging. Geostatistical Analyst in ArcGIS 10 was used to create surfaces for fish biomass. Data for this study were collected from 222 stations, which cover 22 fish species by 2 seasons (spring and fall). In order to increase the sample size for geostatistical analysis, the 22 fish species were combined into 10 groups based on taxonomic and functional similarities (Table 1). Then, Ordinary Kriging was used to create surfaces of fish biomass. For Kriging modeling, a histogram was drawn and a normal QQ plot was used to explore the distribution. Trend Analysis was then used to study the trends in the data, which could be related to water depths and geospatial locations. Based on those preliminary studies, Geostatistical Analyst was used to build the Kriging model. The model parameters were chosen based on the data and the trends that were discovered from preliminary studies. The normality assumption for Kriging was not satisfied for some species groups (i.e., demersal fish in fall, baitfish in fall, river herring in spring and fall, large gamefish in fall, and skates in fall), and therefore Kriging failed. For those cases, Inverse Distance Weighting (IDW) was used to create the surfaces. Major outputs from Kriging and IDW include maps of prediction. The mean predicted abundances for fall and spring seasons were included in the framework (see Figures 4 and 5 for examples of the modeled surfaces).

Table 1. Taxonomic/functional groupings of species identified in fishery-independent trawl data.

Group	Common Name	Scientific Name
Lobster	American lobster	*Homarus americanus*
Sea Scallop	Atlantic sea scallop	*Placopecten magellanicus*
Squid	Longfin squid	*Loligo pealei*
Demersal fish	Atlantic cod	*Gadus morhua*
	Silver hake	*Merluccius bilinearis*
	Scup	*Stenotomus chrysops*
	Goosefish	*Lophius americanus*
Flatfish	Yellowtail flounder	*Limanda ferruginea*
	Summer flounder	*Paralichthys dentatus*
	Winter flounder	*Pseudopleuronectes americanus*
Baitfish	Atlantic herring	*Clupea harengus*
	Atlantic mackerel	*Scomber scombrus*
	Butterfish	*Peprilus triacanthus*
River Herring/Smelt	Alewife	*Alosa pseudoharengus*
	American shad	*Alosa sapidissima*
	Blueback herring	*Alosa aestivalis*
Medium Gamefish	Tautog	*Tautoga onitis*
	Black sea bass	*Centropristis striata*
Large Gamefish	Bluefish	*Pomatomus saltatrix*
	Striped bass	*Morone saxatilis*
Skates	Little skate	*Leucoraja erinacea*
	Winter skate	*Leucoraja ocellata*

A considerable amount of error is associated with creating a surface from the trawl survey point data. However, biologically reasonable trends can be seen. For example, predicted lobster abundance is high close to the mouth of Narragansett Bay in fall (Figure 4) and more dispersed in the spring (Figure 5). This trend is consistent with their annual offshore migration in the winter (Fogarty et al., 1980).

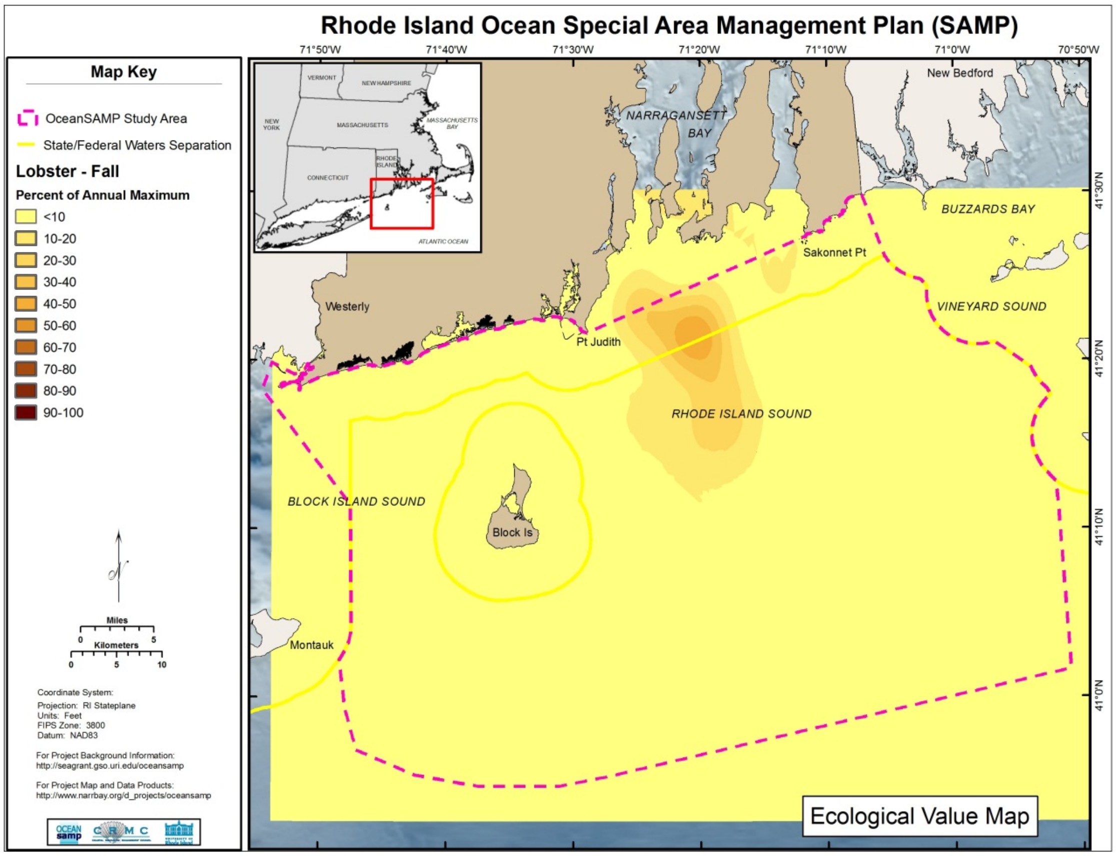


Figure 4. Lobster abundance during the fall season (generated by Kriging), represented as percent of the annual maximum value.

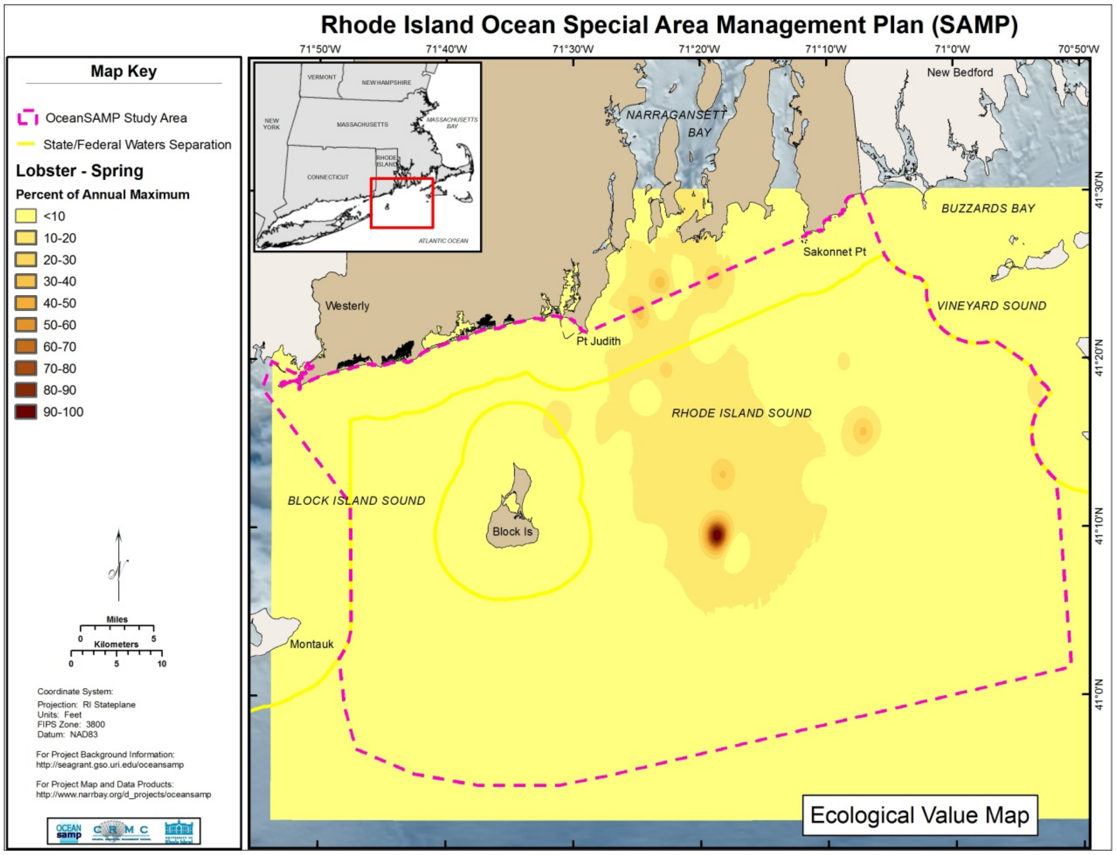


Figure 5. Lobster abundance during the spring season (generated by Kriging), represented as percent of the annual maximum value.

2.4 Birds

To assess current spatial and temporal patterns of avian abundance and movement within the RI Ocean SAMP study area, as well as to identify the most common bird species using RI Ocean SAMP waters, aerial, ship-based, and land-based surveys were conducted by the URI's Department of Natural Resources Science. For a detailed discussion of survey methodologies and preliminary results, refer to Paton et al. (2010).

Nearshore and offshore ship-based line-transect surveys were conducted approximately once per month from February to May 2009 on two 7.4 by 9.26 km grids and then approximately four times per month from June 2009 until March 2010 on eight 7.4 by 9.26 km grids (Figure 6). These surveys were designed to quantify the density and abundance of all species of waterbirds within each survey grid. Using a chartered vessel operating at constant speed, all individuals observed within a moving "box" 300 m ahead of and 300 m perpendicular to the vessel were recorded. Environmental data were also recorded, as well as anthropogenic influences that may have attracted birds to the transect, such as fishing boats or floating debris, etc.

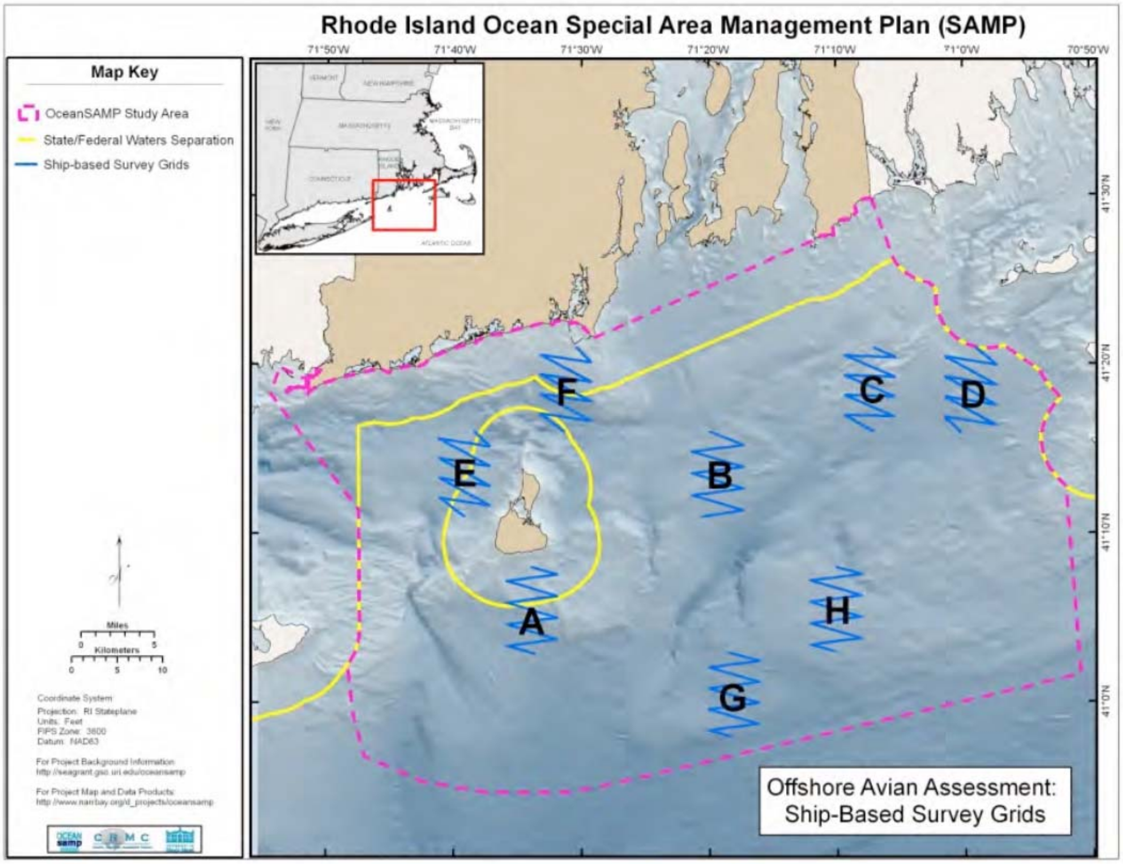


Figure 6. Locations of nearshore and offshore ship-based survey grids (Paton et al, 2010, Figure 24 therein).

The ship-based survey data were used to create surface density models to visually depict the abundance distribution of species common to the RI Ocean SAMP study area. The surface density models relate survey observations with depth and distance to land to predict densities across sampled and un-sampled areas. A grid made up of 2 km by 2 km cells was overlaid on the study area and populated with predicted abundance for each cell. Based on the predictions for each of the grid cells, abundance distribution maps were generated for eight species groups by season (Table 2). These abundance maps represent foraging areas for the species evaluated, and do not include movement corridors (see Figure 7 for an example abundance distribution map). A variance component was also calculated for each model. Because the abundance maps are based on a predictive model based on behavior (rather than a spreading model such as Kriging) and patchy observational data, some artifacts of the model are apparent in the maps, namely the light and dark "contours" of abundance at varying distances from shore that result from the distance-from-land based model used for the surfaces (Figure 7). For a more detailed discussion of the development and application of the surface density models, refer to Paton et al. (2010).

Table 2. Bird groups included in the Surface Density Model.

Bird Group	**Species Included**	**Survey Data Included**
Loons	Common loon (*Gavia immer*)	Aerial survey (winter, spring)*
Alcids	Razorbill (*Alca torda*) Common murre (*Uria aalge*) Dovekie (*Alle alle*)	Ship survey (winter), Aerial survey (spring)
Gulls	Great black-backed gull (*Larus marinus*) Herring gull (*Larus argentatus*) Laughing gull (*Leucophaeus atricilla*)	Ship survey (winter, spring, summer, fall)
Gannets	Northern gannet (*Morus bassanus*)	Ship survey (winter, spring, fall)
Sea Ducks	Common eider (*Somateria mollissima dresseri*) Surf scoter (*Melanitta perspicillata*) Black scoter (*Melanitta nigra americana*)	Aerial survey (winter, spring)*
Shearwaters	Cory's shearwater (*Calonectris diomedea*) Greater shearwater (*Puffinus gravis)*	Ship survey (summer)
Terns	Common tern (*Sterna hirundo*) Roseate tern (*Sterna dougallii*)	Aerial survey (summer)
Petrels	Wilson's storm-petrel (*Oceanites oceanicus*)	Ship survey (summer)

*Survey data were unavailable for the fall season for loons and sea ducks, but these groups are both abundant in the fall in the RI Ocean SAMP area. As a result, spring surface density models were used as a proxy for fall surface density models for these two species groups.

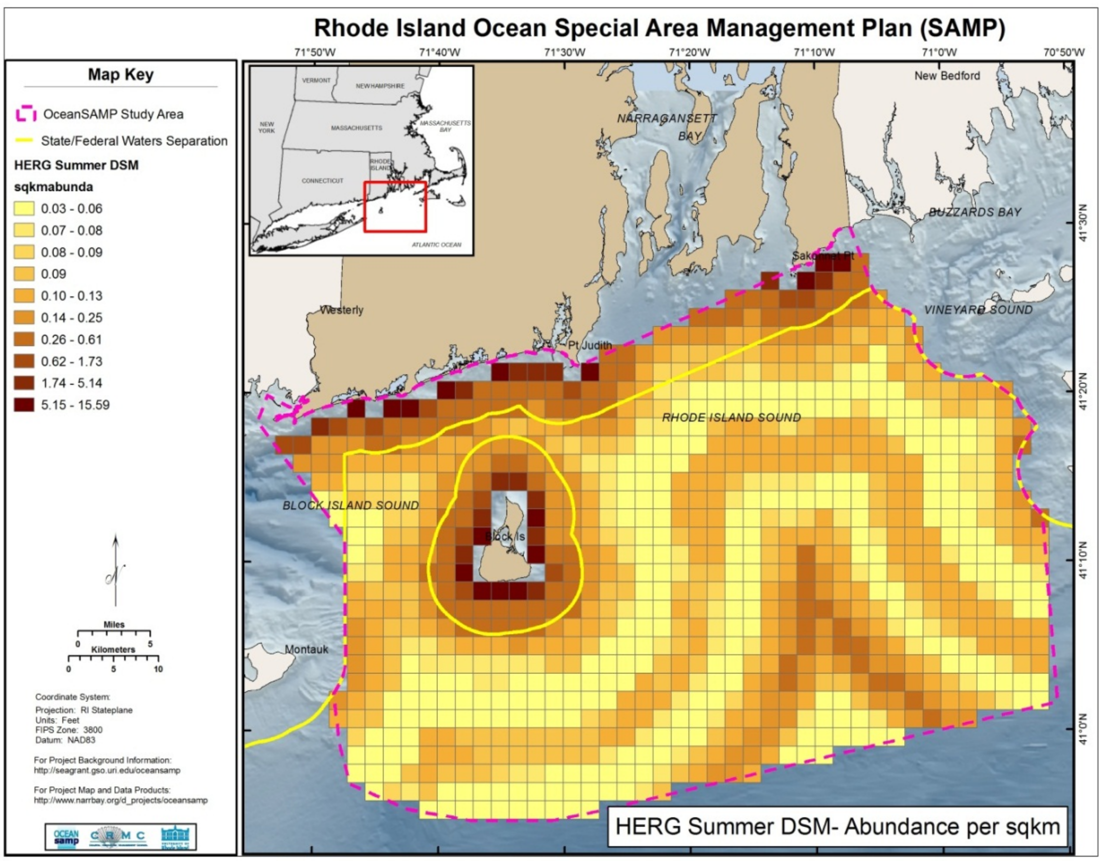


Figure 7. Example abundance distribution map (predicted summer herring gull abundance per square kilometer) (Paton et al. 2010).

Based on both land-based and ship-based survey counts, Paton et al. (2010) have identified 25 waterbird species that commonly inhabit and/or use the waters of the RI Ocean SAMP area. Common eider are the most abundant user of nearshore waters (≤ 3 km from shore), followed by the herring gull and surf scoter. Offshore waters (> 3 km from shore) are utilized most heavily by northern gannets, followed by Wilson's storm-petrels, and herring gulls. Gulls appear to be one of the major users of RI Ocean SAMP waters, both inshore and offshore, and throughout the seasons. In general, bird life is most diverse and abundant during fall and spring migration periods, and during winter (Paton et al., 2010).

2.5 MARINE MAMMALS

Data for cetaceans and pinnipeds were provided by Robert Kenney (URI). The procedure for data collection and analysis is described in Kenney and Vigness-Raposa (2009). All data described below and used in the ecological value analysis were normalized sightings per unit effort (SPUE) values. Figure 8 is an example of the modeled SPUE surfaces incorporated into the framework for marine mammals. Similarly, Kenney and Vigness-Raposa (2009) classified all species into five priority categories for the RI Ocean SAMP area. All species with sufficient data records were included in this ecosystem analysis regardless of priority ranking.

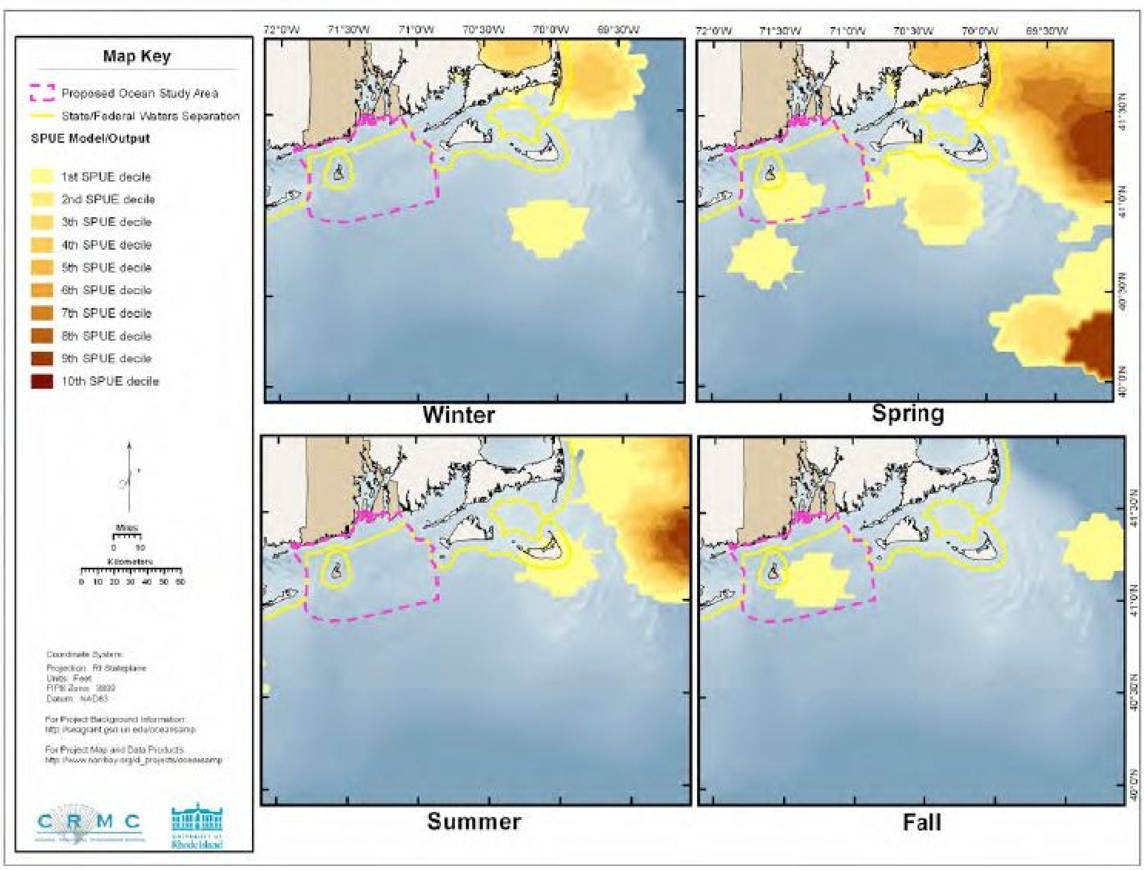


Figure 8. Example modeled-predicted surface of seasonal relative abundance (North Atlantic right whale) (RI Ocean SAMP, Figure 2.32(a) therein).

2.5.1 Distributions of Cetaceans in RI Ocean SAMP Area

Thirty species of cetaceans (whales, dolphins, and porpoises) have been observed in the offshore waters of Rhode Island. Many of these have been observed only occasionally due to many factors including widely dispersed populations and preferred habitat in other locations. A full account of all species observed can be found in Kenney and Vigness-Raposa (2009).

Cetaceans that were observed frequently enough to allow statistical interpretation and are included in the analysis are: North Atlantic right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), harbor porpoise (*Phocoena phocoena*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), short-beaked common dolphin (*Delphinus delphis*), common minke whale (*Balaenoptera acutorostrata*), pilot whales (long-finned, *Globicephala melas*, and short-finned, *G. macrorhynchus*), and common bottlenose dolphin (*Tursiops truncatus*).

Many of these species have higher relative abundances east of Cape Cod and in offshore waters south of the RI Ocean SAMP area. Of all the species analyzed, North Atlantic right whales are the species of greatest concern. Right whales are currently protected in a large portion of the RI Ocean SAMP waters November through April by requiring large ships to maintain speeds of 10 knots or less through the Block Island Seasonal Management Area (SMA, Figure 9). Right whales can be found in Rhode Island waters during any season, though the modeled abundance shows presence only in spring and fall (Kenney and Vigness-Raposa, 2009; Figure 8). The SMA is not included in the framework, but rather should be utilized as an interpretation tool when evaluating potential projects.

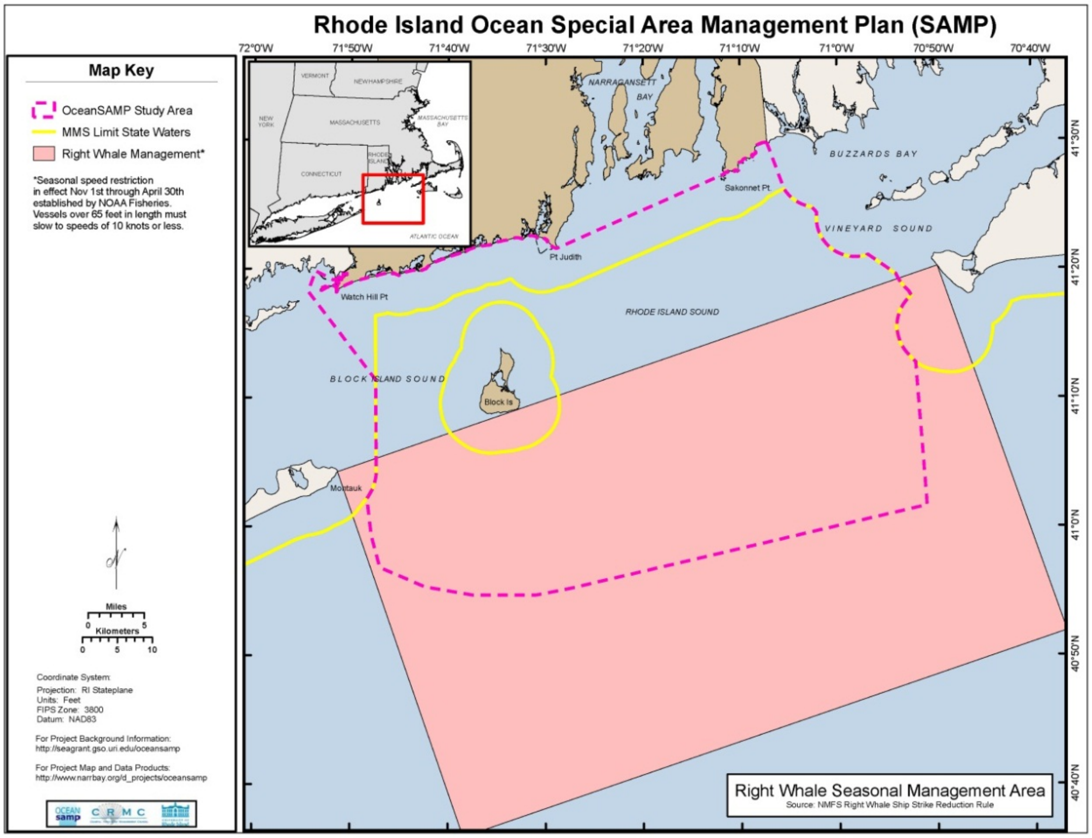


Figure 9. NMFS right whale seasonal management area. Seasonal speed restrictions are in effect November 1st through April 30th. Vessels over 65 feet (19.8 meters) in length must slow to speeds of 10 knots (5.1 m/sec) or less (RI Ocean SAMP, Figure 7.3 therein).

2.5.2 Distributions of Pinnipeds in RI Ocean SAMP Area

Pinnipeds found in the RI Ocean SAMP area include five species of seals: harbor seal (*Phoca vitulina*), gray seal (*Halichoerus grypus*), harp seal (*Pagophilus groenlandicus*), hooded seal (*Cystophora cristata*), and ringed seal (*Pusa hispida*) (Kenney and Vigness-Raposa, 2009). Of these species, harbor seals are common in the RI Ocean SAMP area, particularly along Block Island, and are considered seasonal residents of Rhode Island. Harp, hooded, and gray seals are also all common in the RI Ocean SAMP area, while the ringed seal is rare.

Unlike cetaceans, pinnipeds also use the terrestrial environment, mainly as "haul-out" sites for activities such as resting. When out of the water, they are usually easily startled by natural and anthropogenic activities (Richardson, 1995). Narragansett Bay and Block Island have many haul-out sites used primarily by harbor seals (Schroeder, 2000). These locations are important to pinniped species and should be considered in the siting of offshore projects. Similar to the right whale SMA, pinniped haul-out locations are not included in the framework, but should be used as an additional tool to evaluate potential projects.

Distinguishing between species of seals at sea is difficult during a survey, and some aerial surveys (e.g., those targeting right whales) may not spend the time to differentiate harbor and gray seals in large, mixed-species haul-outs. Therefore, the data analyzed contained a large number of seal sightings that were not identified to species. Because of this, the modeled relative abundance of seals was calculated by combining all records of seals. Abundance is highest in Narragansett Bay and between the south shore of Cape Cod and the islands during fall, winter, and spring (Kenney and Vigness-Raposa, 2009).

2.6 SEA TURTLES

There are four sea turtle species found in the waters of the north Atlantic off Rhode Island and southern Massachusetts. In the RI Ocean SAMP area, leatherback sea turtles (*Dermochelys coriacea*) are common, and loggerhead sea turtles (*Caretta caretta*) are the most common. The Kemp's ridley (*Lepidochelys kempii*) sea turtle has been documented in significant numbers in Cape Cod Bay in the summer, but data are lacking on the migration path these turtles follow and where they occur in the RI Ocean SAMP area. However, because the Kemp's ridley inhabits coastal waters and embayments, it should be considered when assessing ecological value of the area. The green (*Chelonia mydas*) sea turtle is also a coastal species, feeding on eelgrass and other aquatic grasses, and has rarely been sighted in the Northeast in the last several decades. It is possible that restoration of eelgrass beds in the Northeast and warming water temperatures may lead to range expansion of the green sea turtle into the RI Ocean SAMP region in the future.

Of the four turtle species, to date only leatherbacks and loggerheads have been sighted with enough frequency in the RI Ocean SAMP region for abundance patterns to be analyzed, although incomplete and/or unavailable datasets may ultimately tell a different story. See Kenney and Vigness-Raposa (2009) for methods and procedures regarding the relative abundance analysis. Figure 10 is an example of the model-predicted SPUE surfaces incorporated into the framework for sea turtles.

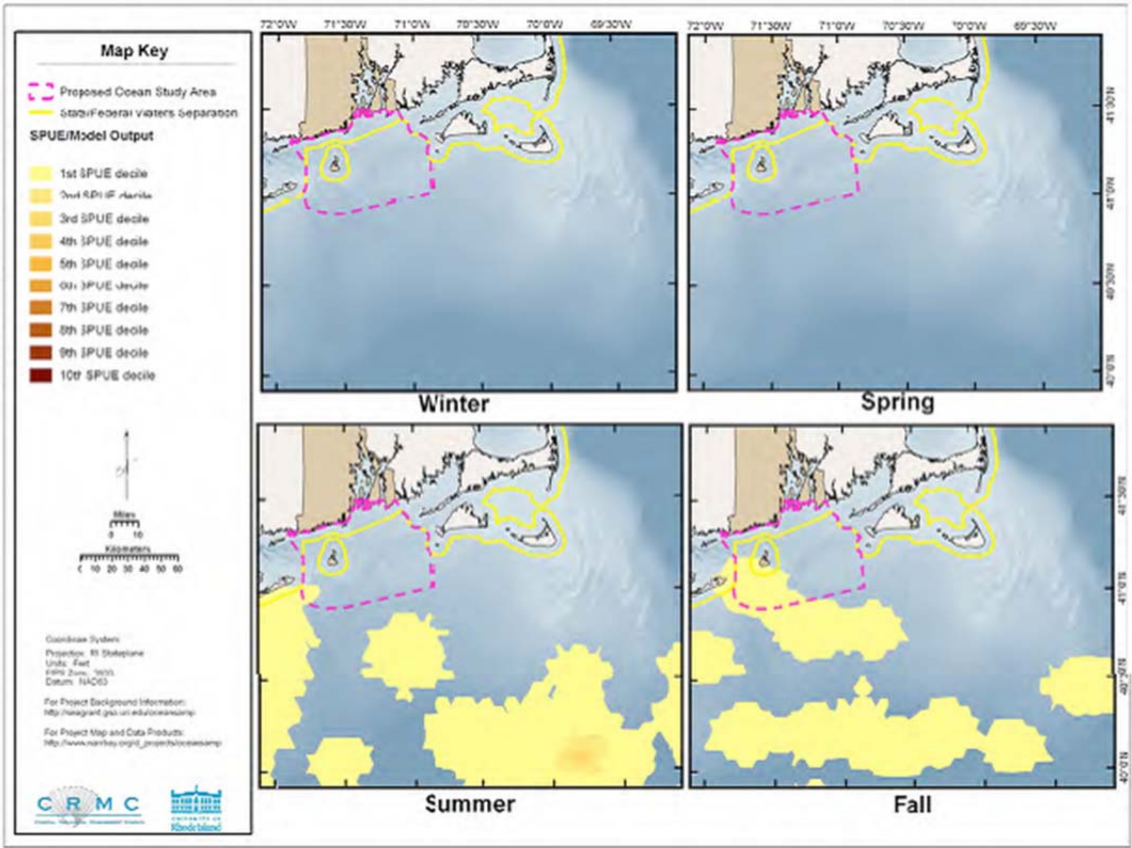


Figure 10. Example model-predicted surface of seasonal relative abundance of loggerhead sea turtle (Kenney and Vigness-Raposa [2009], Figure 71 therein).

While combining the turtle data is not advised because of the differences in life histories between the species, it is likely that conservation methods made for one species of sea turtle will benefit the others (Kenney and Vigness-Raposa, 2009). Therefore, even though only the leatherback and loggerhead are represented in the EVM for the RI Ocean SAMP area, all four species would likely benefit from mitigation or conservation methods directed at individual sea turtle species.

LITERATURE CITED

Bohaboy, E., Malek, A., and Collie, J. 2010. Ocean Baseline Characterization: Data Sources, Methods, and Results. Rhode Island Ocean Special Area Management Plan, University of Rhode Island, Kingston, RI.

Codiga, D.L., D.S. Ullman. 2010. Characterizing the Physical Oceanography of Coastal Waters Off Rhode Island, Part 1: Literature Review, Available Observations, and A Representative Model Simulation. Appendix to Rhode Island Ocean Special Area Management Plan, 169 pp. Available online at: ftp://po.gso.uri.edu/pub/downloads/codiga/osamp/reports/PhysOcPart1-OSAMP-CodigaUllman2010.pdf

Fogarty, M.J., Borden, D.V.D. and Russell, H.J. 1980. Movements of tagged American lobster, *Homarus americanus*, off Rhode Island. Fishery Bulletin 78(3): 771-780.

Hyde, K.W. Personal communication. 5/20/2010. NOAA NMFS Laborartory, Narragansett, Rhode Island.

Kenney, R.D., and Vigness-Raposa, K.J. 2009. Marine Mammals and Sea Turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and Nearby Waters: an Analysis of Existing Data for the Rhode Island Ocean Special Area Management Plan. Draft Technical Report, University of Rhode Island, Kingston, RI.

Kostylev, V.E., Hannah, C.G., 2007. Process-driven characterization and mapping of seabed habitats, in: Todd, B.J., Greene, H.G. (Eds.), Mapping the seafloor for habitat characterization: Geological Association of Canada. Geological Association of Canada, pp. 171-184.

Paton, P., Winiarski, K., Trocki, C., and McWilliams, S. 2010 Spatial Distribution, Abundance, and Flight Ecology of Birds in Nearshore and Offshore Waters of Rhode Island. Interim Technical Report for the Rhode Island Ocean Special Area Management Plan, University of Rhode Island, Kingston, RI.

Richardson, W.J. 1995. Chapter 9: Documented Disturbance Reactions. In: Marine Mammals and Noise, pp. 241-324. Richardson, W.J., Malme, C.I., Greene, C.R., and Thomson, D.H. (eds.), Academic Press, CA.

Schroeder, C. L. 2000. Population Status and Distribution of the Harbor Seal in Rhode Island Waters. M.S. thesis. University of Rhode Island, Graduate School of Oceanography, Narragansett, RI.

Shumchenia, E.J., Grilli, A., King, J.W., Spaulding, M. 2012. Scope for Growth and Disturbance Data for the RI Ocean SAMP Area. Unpublished Data.

Spaulding, M.L., Grilli, A., and Damon, C., and Fugate, G. 2010. Application of Technology Development Index and principal component analysis and cluster methods to ocean renewable energy facility siting. Marine Technology Society Journal 44(1): 8-23.

APPENDIX C

LITERATURE REVIEW OF ECOLOGICAL VALUATION APPROACHES FOR MARINE ECOSYSTEMS

1.0 INTRODUCTION

Assigning value to subareas or zones of the marine environment is not an easy task. Marine environments are intricately complex, typically multifaceted, and provide many services both to natural resources (i.e., fish and wildlife) and to humans. Past valuations have attempted to measure ecological importance, goods and services provided to humans, or both. The outcome of a valuation of a selected area can vary greatly depending on what is being examined. As with any scientific study, clear definitions of the descriptive terms used and what is being measured are pertinent. Methods of valuation in the marine environment have evolved from land-based biodiversity and zoning assessments, natural resource management, marine protected area (MPA) siting analyses, and most recently marine spatial planning (MSP) efforts. Because this science is rooted in both socio-economic and environmental practices, there is cross over in descriptive terminology making accurate definitions all the more important.

The socio-economic definition of the term "value" refers to the goods and services provided by the marine ecosystem, or the value of an area in terms of importance for human use (Nunes and van den Bergh, 2001; De Groot et al., 2002). Human uses of biological resources include consumptive uses (e.g., commercial fisheries harvest, recreational fishing), non-consumptive uses (e.g., scuba diving, wildlife viewing), and non-use (e.g., intrinsic, bequest) values (Freeman, 1993; Kopp and Smith, 1993; Unsworth and Bishop, 1994; and Smith, 1996). This socio-economic definition or inference of the term "value" (which is often tied to a monetary unit), is more traditional and rooted in economic theory.

Ecosystem-based management is an "integrated approach to management that considers the entire ecosystem, including humans" (McLeod and Leslie, 2009). Ecosystem-based management is place- or area-based, as it focuses on a specific ecosystem and the activities affecting it (Douvere, 2008). The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive, and resilient condition so that it can provide the services humans want and need. The emphasis on managing places is a key characteristic of ecosystem-based management and differs from past management approaches in that it considers the cumulative impacts of different sectors, as opposed to focusing on a single species, sector, or activity (Douvere, 2008; McLeod and Leslie, 2009). Several ecosystem-based management practices and tools have developed over the past two decades that assess the marine environment from a holistic, ecological standpoint. However, there is a recognized need for more concrete guidance and operational tools to move the implementation of ecosystem-based management forward (Douvere, 2008). Recently, MSP has emerged as a powerful tool for making ecosystem-based management a reality (Douvere, 2008). MSP is a spatial management practice that considers usage of an area by all sectors (e.g. fisheries, oil and gas industry, renewable energy development). To successfully carry out MSP, baseline scientific and socio-economic data must be mapped to support comprehensive decision making and siting analysis.

With the onset of marine ecosystem-based management, valuation siting analysis efforts have shifted their focus towards biodiversity and ecology. Under the ecosystem-based management approach, valuation of the marine environment should be related to measures of biological and habitat importance. In more recent MSP and ecological valuation efforts, the term "value" has referred to the intrinsic value of marine biodiversity, without reference to anthropogenic use

(DFO, 2005; ENCORA/MARBEF, 2006; Derous et al., 2007a,b,c). Under this definition, value is measured by ecosystem processes such as food production for the food web, refuge from predators, and nesting and nursery habitat.

Marine ecosystems are inherently complex environments having connective processes such that many aspects must be taken into consideration when measuring ecological value. In the marine environment, valuations must consider characteristics and processes of the benthic and pelagic systems, and usage of these by all species (e.g., fish, invertebrates, birds, marine mammals). Typically, ecological valuation approaches have employed multi-criteria evaluation methods while examining spatial ecosystem data, often resulting in a "hot spot" or value map of the area of interest (e.g., Villa et al., 2002; Derous et al., 2007a,b; EOEEA, 2009). Evaluation criteria have been assessed using Delphic and quantitative methods (Brody, 1998). The Delphic method of analysis relies on consensus of a group of experts in the field ranking priorities. This method is often used when time and resources are limited. Selection criteria can also be quantified or scored to minimize the influence of personal bias. Criteria specifically for evaluating the ecological importance of marine environments have evolved over the past fifteen years through small scale studies that identify significant or important marine areas to protect, as well as in larger scale MSP or marine zoning efforts (e.g., Brody, 1998; Roberts et al., 2003a; Lieberknecht et al., 2004; DFO, 2005; Derous et al., 2007a,b,c). The synthesizing criteria developed in these approaches typically identify areas of low to high biodiversity.

The following review summarizes several studies in which methods and criteria for marine ecological valuation were developed.

2.0 OVERVIEW OF SOCIO-ECONOMIC VALUATION

As discussed above, ecological resources provide services to humans, in addition to their intrinsic ecological value (which may be related to biodiversity [Wilson, 1988; Derous et al., 2007a,b,c]) and services to the ecosystem (e.g., nesting and foraging habitat, refuge from predators, food production, nutrient cycling). Human services include consumptive uses (e.g., commercial harvest, recreational fishing), non-consumptive uses (e.g., scuba diving, wildlife viewing, aesthetics, spiritual enrichment), and non-use (e.g., option, bequest, genetic pool, existence) values (Freeman, 1993; Kopp and Smith, 1993; Unsworth and Bishop, 1994; Smith, 1996). Many attempts have been made to measure the value of these services in economic terms, with value being defined as the aggregate "willingness-to-pay" by all individuals for all the services associated with the functioning of the ecosystem (e.g., Freeman, 1993; Smith, 1996). In practice, this approach requires considerable research and site-specific data, relying on proxy markets for ecological services that are not in fact directly traded in the marketplace. If site-specific data are not available, value transfers from other markets or locations are typically made, with a great deal of associated uncertainty. Alternatively, non-market valuation techniques such as Contingent Valuation (CV), which involves questioning samples of people regarding willingness-to-pay for ecological services, are used to estimate monetary values of services. However, these methods are difficult to apply without bias and the results, therefore, are highly variable and uncertain (NOAA, 1992). Arrow et al. (2001) outline the potential biases and errors associated with CV, as well as criteria for reliable CV studies. Of the potential biases and errors associates with CV studies, Arrow et al. (2001) list the following as the most concerning: (1) the CV method can produce results that appear to be internally inconsistent; (2) responses to CV surveys can seem implausibly large in view of the many programs for which individuals might be asked to contribute and the existence of both public and private goods that might be substitutes for the resource(s) in question; (3) most applications of the CV method fail to remind respondents of the budget constraints under which willingness-to-pay spending decisions must be made; (4) respondents may not be provided adequate information about the program they are being asked to value, or may not fully absorb and accept detailed program information as the basis for their responses; (5) in generating aggregate estimates using the CV technique, it is sometimes difficult to determine the extent of the population that is appropriate for determining values; and (6) respondents in CV surveys may actually be expressing feelings about the "warm glow" of donating to a worthy cause, rather than actual willingness to pay for the program in question.

Given these difficulties and data constraints, more recent attempts at ecological valuation have focused on approaches based on biodiversity; and scaling mitigation of equivalent value to lost ecological services has been based on compensatory restoration rather than monetary valuation. Under the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"; 42 U.S.C. § 9601 et seq.), the Clean Water Act (33 U.S.C. § 1251 et seq.), the National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), and the 1990 Oil Pollution Act ("OPA"; 33 U.S.C. § 2701 et seq.), natural resource trustees (i.e., designated government agencies) act on behalf of the public to protect natural resources and make damage claims against parties responsible for injuries to natural resources resulting from discharges of oil, releases of hazardous substances, or physical injury. The compensation is in the form of equivalent ecological and human services to the injuries, often measured by totaling ecologically-equivalent production of biomass or service-years of resource life (NOAA, 1995).

Thus, while monetary valuation is theoretically possible as a metric for mapping values of ecological resources, in practice the approach requires considerable site-specific research effort, is very subjective (as human perception of value is involved), and is highly uncertain.

3.0 RELEVANT MPA EFFORTS AND VALUATION CRITERIA

To efficiently execute MSP management, ecological valuation of broad scale coastal zones and subareas is necessary. Ecological valuation of the marine environment for MSP is a relatively new science, and despite the current global push to implement MSP practices, little guidance exists. There is increasing awareness that rigorous procedures are needed for assessing the value of marine areas; these procedures should be based on objectively chosen criteria and sound scientific monitoring data (Agardy, 2010). Currently, approaches, methods, and protocols for ecological valuation are being developed and tested.

To date, most of the development and refinement of ecological valuation criteria and methods has arisen out of initiatives to identify and designate MPAs. Many different selection approaches have been used for MPAs, from using criteria as general guidelines to more complex methods of scoring and ranking (Brody, 1998). Historically, the selection of MPAs was largely opportunistic or arbitrary; recently, a more Delphic or judgmental approach has been advocated (Agardy, 2010), and many important ecological concepts and valuation methods have evolved and been examined during MPA siting analyses. Ecological valuation for MPA siting differs from valuation for MSP, as MSP valuation is not a process to select areas for conservation according to an objective; rather it should be an overview of baseline ecological value of the study area (Derous et al., 2007a). However, the criteria and methods used for selection of MPAs have greatly informed or helped the development of MSP approaches. The underlying theme of many MPA selection criteria is reflected in the recent MSP studies, tools, case studies, and models. Several relevant assessments and studies from the MPA literature are discussed below.

3.1 HABITAT-LEVEL APPROACHES

Attaining comprehensive data with ample spatial coverage for ecological valuations can be challenging. In many cases, biological data are patchy and/or focused on a particular area of concern. The sampling coverage needed to truly represent broad scale study areas is often unavailable and costly to obtain (e.g. characterization of the benthic habitat). Amalgamation of data sets from studies performed at various locations and by various researchers may lead to standardization and effort issues inherent to the sampling approaches, although these amalgamation efforts are still useful if standardization is handled properly and limitations are well defined. Modeling data layers based on spatial interpolations between points, or extrapolating a surface as a function of a variable with ample spatial coverage has been used to address the data gap problem (Degraer et al., 2008; EOEEA, 2009; Greene et al., 2010). For example, in the Belgian part of the North Sea, Degraer et al. (2008) constructed a habitat suitability model for soft sediment communities. It was determined through statistical analysis of benthic samples that median grain size and sediment mud content were the two most important environmental variables determining the macrobenthic community. Because sediment spatial distribution was well known, model-based predictions could be made regarding the biological communities for the unsampled areas.

To further investigate the data insufficiency problem, Ward et al. (1999) evaluated the use of four different ecosystem-level (i.e., "coarse-filter") surrogates as the basis for identifying marine reserves in Jervis Bay, Australia: (1) habitat categories, and species-level assemblages of (2) fish, (3) invertebrates, and (4) plants (e.g., algae, seagrasses). The performance of these surrogates was evaluated based on the total number of taxa (i.e., species richness) contained in marine reserves generated by a number of selection simulations. This approach allowed for an assessment of, for example, the extent to which reserves chosen solely on the presence of fish assemblages would also coincidentally include taxa of invertebrates or plants. Ward et al.'s (1999) findings suggest that habitat-level surrogates may be appropriate for initially identifying areas of high priority, without the need for extensive species-level survey data. In addition, site selection based on habitat categories would have a lower risk of failing to coincidentally include certain taxonomic groups.

3.2 COMPUTER-BASED APPROACHES

In regional conservation planning situations with multiple conservation targets and thousands of potential sites, computer-based siting algorithms can be useful in reducing the enormous number of potential reserve systems to a more manageable set of scenarios (Leslie et al., 2003). The various siting algorithms available can be grouped into three main types: iterative, optimizing, and simulated annealing.

Iterative algorithms use a set of criteria to order each planning unit and then choose the highest ranking site. Some of the most popular iterative or heuristic algorithms aim to achieve representation of rare species or maximize species richness. While useful, these approaches generate only one solution and it is unlikely to be the optimal one (Leslie et al., 2003).

Using standard mathematical programming methods, optimizing algorithms, such as an Integer Linear Program (ILP) can be used to find the optimal reserve-selection solution. ILPs determine how to maximize or minimize a particular function, subject to several constraints (represented as linear relationships). ILPs can be used to find the optimal reserve-selection solution; however, they also produce only one solution. In a conservation planning situation, multiple solutions are often more desirable. Furthermore, if a conservation planner prefers a spatially-clustered reserve system, optimal solutions cannot be guaranteed with this method (as it is a Non-linear Integer Programming problem) (Leslie et al., 2003). Another limitation is that because of the computing time required, the optimization method fails in situations where there are more than a few hundred potential planning units (Possingham et al., 2000).

Simulated annealing is a flexible optimization algorithm that starts with a random reserve system and then iteratively explores trial solutions by making sequential random changes to the set of planning units. In each iteration, the previous set of units is compared with the new set, and the best one is accepted (Possingham et al. 2000). The strength of this approach is its avoidance of local optima and more opportunities to reach the global minimum. This approach has been shown to outperform simpler iterative or heuristic algorithms (Possingham et al., 2000).

Using benthic habitat data from the Florida Keys, Leslie et al. (2003) demonstrated the use of simulated annealing to identify marine reserve systems that met specified levels of habitat representation. To apply this approach, they used the reserve design software package SPEXAN (an acronym for SPatially EXplicit ANnealing). Using the reserve scenarios generated by simulated annealing, the authors also conducted an irreplaceability analysis to determine how many times each site was chosen during 100 runs. This analysis identified sites that were consistently selected in the reserve network scenarios, as well as sites that were never or infrequently chosen. Identifying consistently chosen (i.e., "irreplaceable") sites is a useful output of siting algorithms that could be used to indicate priority areas for conservation.

Although Leslie et al.'s (2003) analysis focused on using habitat representation to select reserve sites, the authors note that many other types of data could be incorporated into the algorithms, such as occurrences of species of concern, protected sites, recreational and fishing pressure, land-based activities, etc. They also stated that information regarding currents and other oceanographic features could be incorporated into the siting algorithm through the formulation of an additional constraint.

Villa et al. (2002) used spatial multiple criteria analysis (SMCA) to integrate objective data with stakeholder priorities in the development of a proposed zoning plan for the Asinara Island National Marine Reserve in Italy. SMCA is one method among a diverse set of techniques known as multicriteria evaluation. These techniques are widely used in both economic analyses and environmental impact assessments and are rooted in land-based urban and regional zoning and management (Voogd, 1983; Nijkamp et al., 1990; Agardy, 2010). By coupling geographic information system-based land assessment with a formal analysis of design priorities, SMCA can be used to objectively evaluate the suitability of various marine areas for different uses and levels of protection. In addition to planning, techniques based on SMCA can also be used to monitor the effectiveness of MPA management and evaluate whether objectives are being met according to expected time frames (Villa et al., 2002). One of the strengths of SMCA is that both quantitative and semi-quantitative information/ranks can be combined in the analyses without the need for special data processing (Villa et al., 2002).

Concordance/discordance analysis is a fundamental technique in SMCA in which a set of attributes is ranked according to a concordance (or discordance) score computed based on "priority weights" that reflect the importance of each attribute within a particular scenario (Villa et al., 2002). These concordance scores are then used to create a map for each land- or marine-use scenario depicting the agreement between the specified priorities and the features of the area of interest. The maps from several different scenarios can then be aggregated and analyzed using GIS (Agardy, 2010). To inform the proposed zoning plan for the Asinara Island reserve, Villa et al. (2002) aggregated the available data into five higher-level variables, as described below:

- Natural Value of the Marine environment (NVM). This map aggregated values related to (1) the diversity and size distribution in the benthic and aquatic communities, (2) the presence of endemic or rare species, and (3) the presence and status of conservation habitats that have crucial roles in maintaining ecosystem function (e.g., nursery areas).

- Natural Value of the Coastal environmental (NVC). This map was obtained by aggregating information relative to important coastal endemic species, the suitability of habitats for return or reintroduction of key species, and the ability of the coastal habitat to support key species that nest on the mainland. The aggregation was performed by applying SMCA to the raw information.
- Value of Area for Recreational Activities (RAV). This map was also obtained by assigning relative importance values to each variable included and performing a SMCA to characterize the value as concordance of the area characteristics with the suitability for each feature. The final value map was obtained from the results of the SMCA after weighting with the accessibility of the area.
- Values of the area for Commercial exploitation of Resources (CRV). This map was prepared based on maps identifying areas of traditional and artisan fishing activity and the general suitability of areas for such practices.
- Degree of accessibility of area (Ease of Access, EAC). This was map prepared based on distance buffering of maps identifying marine access routes and existing harbors. The EAC map was used both as a "benefit" value for scenarios where access is allowed and encouraged, and as a "cost" factor in high protection scenarios, being a proxy for potential disturbance.

These various GIS layers were then combined into one surface of evaluation units. Evaluation units were derived by processing the data contained in the initial set of variable layers to identify all areas where unique combinations of variable values exist. Then various priority weights were applied to the evaluation unit layer to produce a final concordance map. These priority weights were developed through consultation with various stakeholders for four different protection levels.

There have been several MPA siting studies conducted using a decision support software program called Marxan (Stewart et al., 2003; Richardson et al., 2006; Klein et al., 2008; Smith et al., 2009). Marxan (Ball and Possingham, 2000; Possingham et al., 2000) is used to identify potential reserves or reserve networks that meet explicit conservation objectives. Essentially, Marxan software includes or excludes a planning unit from being reserved, implicitly assuming two zones: reserved or not reserved. The biological criterion that Marxan uses to discriminate between marine areas is the number of species or communities contained within a designated level of representation. The Marxan method has been applied to marine reserve case studies in California, the United Kingdom, Australia, and elsewhere.

The recently-developed Marxan with Zones (Watts et al., 2009) is an analytic tool that expands on the basic marine reserve design problem to incorporate new functionality and broaden its utility for practical application. This newer version of the Marxan tool shifts away from the binary decision framework towards a multi-use seascape planning paradigm supporting allocation of planning units to a range of different management actions. Marxan with Zones is designed to improve planning for marine protected area (MPA) systems, but also for application to a wider range of natural resource management and spatial planning problems.

3.3 Valuation Criteria

Roberts et al. (2003a,b) identified criteria for objectively assessing the biological value of areas being considered for marine reserves. The overall goal of the evaluation scheme was to promote the development of reserve networks that would maintain biodiversity and ecosystem functioning at large scales. In certain past cases, socio-economic evaluation criteria for an area had been given equal or greater weight than the ecological considerations. This can lead to selection of areas with little biological value that fail to meet many of the management and conservation objectives (Roberts et al., 2003a,b). Roberts et al. (2003a) argue that in general, biological evaluation should precede and inform social and economic evaluation of potential reserve sites.

The criteria developed in Roberts et al. (2003a,b) concentrate on the assessment of sites according to their biodiversity, the processes that support that biodiversity, and processes that aid fisheries management and provide other human benefits. Valuation criteria representing the biodiversity of sites included: biogeographic representation, habitat heterogeneity, endemism, and presence of species or populations of special interest (e.g., threatened species). Valuation criteria used to assess sustainability of biodiversity and fishery values included: size of reserves necessary to protect viable habitats, presence of exploitable species, vulnerable life stages, connectivity between reserves, links among habitats, and provision of ecosystem "services" for people. Human threats and natural catastrophes were also accounted for and enabled candidate sites to be eliminated from consideration if risks were too great, but also helped prioritize among sites where threats could be mitigated by protection.

The International Maritime Organization (IMO) has put forth guidelines for the identification and designation of Particularly Sensitive Sea Areas (PSSAs) (IMO, 2006). A PSSA is defined by the IMO as an area in need of special protection due to its significance for recognized ecological, socio-economic, or scientific attributes, where such attributes may be vulnerable to damage by international shipping activities. The guidelines state that in order to be identified as a PSSA, the area should meet at least one of the criteria defined below. Additional factors are also considered in order to assess the vulnerability of the area to impacts from international shipping; these factors are beyond the scope of this review, and are therefore not discussed further.

- Ecological criteria
    - Uniqueness or rarity – An area or ecosystem is considered unique if it is the only one of its kind (e.g., habitats of rare, threatened, or endangered species that occur only in one area). An area or

ecosystem is considered rare if it only occurs in a few locations or has been seriously depleted across its range. Nurseries or certain feeding, breeding, or spawning areas may also be considered rare or unique.

- Critical habitat – An area that may be essential for the survival, function, or recovery of fish stocks or rare or endangered marine species, or for the support of large marine ecosystems.
- Dependency – An area where ecological processes are highly dependent on biotically structured systems (e.g., coral reefs, kelp forests, mangrove forests, seagrass beds). Dependency also embraces the migratory routes of fish, reptiles, birds, mammals, and invertebrates.
- Representativeness – An area that is an outstanding and illustrative example of specific biodiversity, ecosystems, ecological or physiographic processes, or community or habitat types or other natural characteristics.
- Diversity – An area that may have an exceptional variety of species or genetic diversity or includes highly varied ecosystems, habitats, and communities.
- Productivity – An area that has a particularly high rate of natural biological production.
- Spawning or breeding grounds – An area that may be a critical spawning or breeding ground or nursery area for marine species which may spend the rest of their life-cycle elsewhere, or is recognized as migratory routes for fish, reptiles, birds, mammals, or invertebrates.
- Naturalness – An area that has experienced a relative lack of human-induced disturbance or degradation.
- Integrity – An area that is a biologically functional unit; an effective, self-sustaining ecological entity.
- Fragility – An area that is highly susceptible to degradation by natural events or by the activities of people.
- Bio-geographic importance – An area that either contains rare biogeographic qualities or is representative of a biogeographic "type" or types, or contains unique or unusual biological, chemical, physical, or geological features.

- Social, cultural and economic criteria
    - Social or economic dependency – An area where the environmental quality and the use of living marine resources are of particular social or economic importance, including fishing,

recreation, tourism, and the livelihoods of people who depend on access to the area.

    - Human dependency – An area that is of particular importance for the support of traditional subsistence or food production activities or for the protection of the cultural resources of the local human populations.
    - Cultural heritage – An area that is of particular importance because of the presence of significant historical and archaeological sites.
    - Scientific and educational criteria

- Research – An area that has high scientific interest.
    - Baseline for monitoring studies – An area that provides suitable baseline conditions with regard to biota or environmental characteristics, because it has not had substantial perturbations or has been in such a state for a long period of time such that it is considered to be in a natural or near-natural condition.
    - Education – An area that offers an exceptional opportunity to demonstrate particular natural phenomena.

In 2007, the Convention on Biological Diversity (CBD) organized a workshop in the Azores to develop a consolidated set of scientific criteria for identifying ecologically or biologically significant marine areas in need of protection, as well as to compile biogeographical and ecological classification systems for delineating ocean regions and ecosystems (CBD, 2008). The adopted criteria (summarized below) share many similarities with the IMO criteria.

- *Uniqueness or rarity* – Areas that contains unique, rare, or endemic species, populations, or communities; unique, rare, or distinct habitats or ecosystems; and/or unique or unusual geomorphological or oceanographic features.
- *Special importance for life history stages of species* – Areas that are required for a population to survive and thrive, such as breeding grounds, spawning areas, nursery areas, juvenile habitat, and habitats of migratory species (e.g., feeding, breeding, moulting, wintering, or resting areas, migratory routes).
- *Importance for threatened, endangered, or declining species and/or habitats* – Areas containing habitat for the survival and recovery of endangered, threatened, or declining species, or areas with significant assemblages of such species. Includes breeding grounds, spawning areas, nursery areas, juvenile habitat, and habitats of migratory species (e.g., feeding, breeding, moulting, wintering, or resting areas, migratory routes).
- *Vulnerability, fragility, sensitivity, or slow recovery* – Areas that contain a relatively high proportion of sensitive habitats, biotopes, or species that

are functionally fragile (i.e., highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.

- *Biological productivity* – Areas containing species, populations, or communities with comparatively higher natural productivity (e.g., frontal areas, upwellings, hydrothermal vents).
- *Biological diversity* – Areas containing comparatively higher diversity of ecosystems, habitats, communities, or species, or having higher genetic diversity (e.g., seamounts, fronts and convergence zones, cold coral communities, deep-water sponge communities).
- *Naturalness* – Areas with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.

Notabartolo di Sciara and Agardy (2009) describe the first phase in the process of developing a network of representative marine protected areas in areas beyond national jurisdictions in the Mediterranean Sea. As part of the this effort, the authors developed a set of region-specific criteria by adapting other existing criteria, including the Specially Protected Area of Mediterranean Importance (SPAMI) criteria ("Common criteria for the choice of protected marine and coastal areas that could be included in the SPAMI List") listed in Annex I of the Protocol to the Barcelona Convention concerning Specially Protected Areas and Biological Diversity in the Mediterranean (also known as the SPA/BD Protocol). The Annex lists the following criteria for use in assessing the regional value of an area:

- Uniqueness – The area contains unique or rare ecosystems, or rare or endemic species.
- Natural representativeness – The area has highly representative ecological processes, or community or habitat types or other natural characteristics. Representativeness is defined as the degree to which an area represents a habitat type, ecological process, biological community, physiographic feature, or other natural characteristic.
- Diversity – The area has a high diversity of species, communities, habitats, or ecosystems.
- Naturalness – The area has a high degree of naturalness as a result of the lack or low level of human induced disturbance and degradation.
- Presence of habitats that are critical to endangered, threatened or endemic species.
- Cultural representativeness – The area has a high representative value with respect to cultural heritage, due to the existence of environmentally sound traditional activities integrated with nature which support the well-being of local populations.

Notabartolo di Sciara and Agardy (2009) contend that these criteria alone are insufficient to guide the development of a representative network of MPAs in the Mediterranean Sea and suggest integrating the SPAMI selection criteria with other existing criteria used in the development of MPA networks. The authors proposed the following eight criteria for the selection of priority regions in the Mediterranean Sea, based on the SPA/BD Protocol criteria for SPAMIs, and incorporating additional information from other criteria, most notably those adopted by the CBD. The proposed criteria are listed below:

- *Uniqueness or rarity* – Areas that contain unique, rare, or endemic species, populations or communities; unique, rare or distinct, habitats or ecosystems; and/or unique or unusual geomorphological or oceanographic features.
- *Special importance for life history stages of species* – Areas that are required for a population to survive and thrive.
- *Importance for threatened, endangered or declining species and/or habitats* - Areas containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.
- *Vulnerability, fragility, sensitivity, or slow recovery* – Areas containing a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.
- *Biological productivity* – Areas containing species, populations, or communities with comparatively higher natural biological productivity.
- *Biological diversity* – Areas containing comparatively higher diversity of ecosystems, habitats, communities, or species, or having higher genetic diversity.
- *Naturalness* – Areas with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.
- *Cultural representativeness* – Areas with a high representative value with respect to the cultural heritage, due to the existence of environmentally sound traditional activities integrated with nature which support the well-being of local populations.

Considering the various sets of criteria discussed above, it is clear that despite slightly different definitions, there are several common themes in criteria currently used for ecological valuation. Smith and Theberge (1986) conducted a review of criteria used in the evaluation of natural areas, including wetland, freshwater, and marine environments. Their review identified a number of criteria that have been used to identify and evaluate the significance of natural areas. Of the 22 evaluation systems they reviewed, the most common criteria used consisted of the following: rarity, uniqueness (used in 91 percent of the studies); diversity (91 percent); size (50 percent); naturalness (45 percent); representativeness, typicalness (36 percent); and fragility (32 percent).

Brody (1998) reviewed and compared existing selection criteria frameworks for six MPA-related programs in the Gulf of Maine. Ecological characteristics (e.g., representativeness, ecological importance, uniqueness) were the criteria most heavily emphasized in the programs reviewed. Social criteria (e.g., education, recreation, and culture) were the least used criteria among the identified programs. Overall, management objectives that aim to protect natural processes or threatened species place a high priority on criteria that value ecological components of the marine environment, such as representativeness, naturalness, diversity, and ecological sensitivity. Management objectives for MPAs that encourage human use tend to rely more on pragmatic/feasibility criteria, such as accessibility, compatibility, financial resources, and cooperative management. Management objectives that focus on more intensive human use and aim to maintain species/habitats for sustainable human use rely more on economic criteria, such as importance to fisheries, importance to species, and biological productivity. Management objectives that focus on passive human use tend to emphasize criteria such as tourism/recreation, education/interpretation, and uniqueness (e.g., unique features that attract the interest of visitors).

4.0 RELEVANT MSP EFFORTS

In the last decade or so, several countries have begun implementing (or developing) MSP, including Australia, New Zealand, the United Kingdom, the Netherlands, Belgium, Germany, Denmark, Italy, China, West Africa, the United States, Canada and others (Douvere, 2008; Agardy, 2010). Several of these efforts are discussed in the following paragraphs. Most of these international efforts (with the exception of China), have focused on establishing marine reserves and MPAs. However, in Europe (particularly the North Sea area), MSP has become much broader and is more focused on establishing ecosystem-based management, including enhancing efficient use of the marine environment, identifying opportunities for shared use, and resolving use conflicts (both between different sea uses and between users and the environment) (Douvere, 2008).

Under Canada's Oceans Act, the Department of Fisheries and Oceans (DFO) developed a tool or framework to identify ecologically and biologically significant areas to aid in providing these areas a heightened degree of risk aversion in the management of activities (DFO, 2005). In this framework, significant areas are identified based on characteristics of a particular area, and the process-based understanding of important characteristics in terms of ecosystem structure and function. On the conceptual level, the framework uses three main criteria, against which specific areas can be evaluated with regards to their ecological and biological significance, including uniqueness, aggregation, and fitness consequences. For specific cases, in addition to these three criteria, they suggest that resilience and naturalness should also be considered. DFO (2005) suggested that areas should be comparatively evaluated using a probabilistic view for all five criteria. Those areas that rank highly on one or more of the three main criteria for a single species or habitat feature may be considered significant.

DFO (2005) provided some caveats in applying their framework. It needs to be taken into consideration that some of the information sources from well-sampled areas may be “clustered in space,” and may provide a biased view of uniqueness; further consideration and review of qualitative and semi-quantitative methods to help reduce this bias were suggested. Vulnerability of the area (i.e., relative vulnerability of species or structural habitat features to disturbance and relative exposure of sites to likelihood of perturbations) should be considered during the evaluation. Spatial scale on all levels (i.e., for structural habitat, life history function, community structure, and connectivity between sites) should always be taken into account during the area evaluation for all five dimensions. Spatial scale needs to be recognized as a constant source of uncertainty. Temporal scale also needs to be considered during the comparative evaluation between areas.

DFO (2005) provides illustrations of how various ecological functions, including spawning/breeding, nursery/rearing, feeding, migration, and seasonal refugia, would be judged under each of the five ranking criteria considered. Similarly, they provided illustrations of how biodiversity (presence of endangered or threatened species and presence of highly diverse or productive communities) and various structural features, including physical oceanographic features (e.g., tidal mixing zones, convergence zones, polynyas, upwelling zones), strong topography, sponge reefs, deepwater corals, and macrophyte beds would be judged under the five ranking criteria.

As described in Agardy (2010), in 2002 the UK government began a regional planning effort to identify marine areas of conservation interest, as well as areas with development potential for maritime industries. As a pilot project, a partnership of several agencies collected geophysical, hydrographical, nature conservation, ecological, and human-use data and analyzed various planning options for the Irish Sea using GIS and Marxan. As part of the Irish Sea Pilot, areas of national importance for marine conservation were identified with the objective of eventually developing a network of protected sites consisting of representative examples of each habitat type, areas of exceptional biodiversity, and important areas for aggregations of highly mobile species. Criteria used to assess national importance included typicalness, naturalness, size, biological diversity, critical areas for certain stages in the life cycles of key species, and nationally-recognized important marine features (Connor et al., 2002; Lieberknecht et al., 2004). Two approaches for applying criteria were tested. The first approach applied criteria directly at the landscape scale. Previous studies identified the “best examples” of each marine landscape at the regional sea scale. The approach operated under the assumption that marine landscapes would act as surrogates for smaller levels of scale (species, habitats) which would ensure the full representation of biodiversity within the final set of areas. The second approach utilized the reserve selection software Marxan (Ball and Possingham, 2000; Possingham et al., 2000), which aided in the process of identifying nationally import marine areas at a regional scale, especially in data-poor offshore regions. This approach tested how the criteria can be incorporated into Marxan using real data from the Irish Sea. One of the main outcomes of this case study was that the various criteria definitions were found to be too restrictive and only effective in areas with good data coverage. The authors concluded that refined definitions were necessary to make the criteria more applicable.

In 2002, China's "Law on the Management of Sea Use" came into effect and established a management framework and initial regional planning system for development and conservation in the marine environment (Li, 2006; Douvere, 2008). The Law establishes that any individual or entity that plans to use the marine environment must apply in advance and obtain authorization from both the provincial and national government. The Law also imposes a user-fee system. Furthermore, the legislation stipulated that the State Oceanic Administration work with the governments of coastal provinces, autonomous regions, and municipalities to formulate a marine functional zoning plan, under which the marine environment is divided into different functional zones based on criteria related to ecological functions and priority use. The formulation of the marine functional zoning plan was required to follow the basic principles listed below:

- Scientifically defining the functions of the sea area according to such natural attributes as its geographic location, natural resources, and natural environment;
- Making overall arrangements for sea area use among various related sectors according to economic and social development needs;
- Protecting and improving the ecological environment, ensuring the sustainable utilization of the sea area, and promoting the development of the marine economy;
- Ensuring maritime traffic safety; and
- Safeguarding the security of national defense and meeting the needs of the military's use of the sea.

After extensive studies and data collection, the National Marine Functional Zoning Scheme was submitted and approved by the State Council. Any use of the sea must comply with this scheme (Li, 2006).

The most notable and recent concept for marine biological valuation, representing consensus of multiple European researchers, has been developed by Derous et al. (2007a,b,c), where marine biological valuation is defined as the determination of value of the marine environment from a "nature conservation perspective." Their valuation methodology provides an integrated view of "the intrinsic value of marine biodiversity, without reference to anthropogenic use" and purposefully does not include the socio-economic valuation or quantification of goods and services. This methodology entails compilation of biological valuation maps (BVMs) using available marine ecological and biological data where intrinsic value is assessed using biological valuation criteria. BVMs can then be used as baseline data for spatial planning efforts and allow managers and planners to make objective and transparent decisions.

Derous et al. (2007a) present a comprehensive literature search outlining existing biological valuation approaches and assessment criteria (highlighting both terrestrial and marine case studies). The results of their literature review showed that biodiversity can be measured via three "1st order" valuation criteria: rarity, aggregation, and fitness consequence. These criteria are defined as:

- *Rarity* – The degree to which a subzone is characterized by unique, rare, or distinct features (e.g., landscapes, habitats, communities, species, ecological functions, geomorphological, or hydrological characteristics) for which no alternatives exist.
- *Aggregation* – The degree to which a subzone is a site where most individuals of a species are aggregated for some part of the year, or a site which most individuals use for some important function in their life history, or a site where some structural property or ecological process occurs with exceptionally high density.
- *Fitness* consequence – Degree to which an area is a site where the activity(ies) undertaken make(s) a vital contribution to the fitness (i.e., increased survival or reproduction) of the population or species present.

These criteria can be modified based on two other factors: naturalness and proportional importance, which are defined as:

- *Naturalness* – The degree to which an area is pristine and characterized by native species (i.e., absence of perturbation by human activities and absence of introduced or cultured species).
- *Proportional* importance:
  - *Global importance* – proportion of the global extent of a feature (habitat/seascape) or proportion of the global population of a species occurring in a certain subarea within the study area.
  - *Regional importance* – proportion of the regional (e.g., NE Atlantic region) extent of a feature (habitat/seascape) or proportion of the regional population of a species occurring in a certain subarea within the study area.
  - *National importance* – proportion of the national extent of a feature (habitat/ seascape) or proportion of the national population of a species occurring in a certain subarea within territorial waters.

Biological valuation methods developed by Derous et al. (2007a) do not give information on potential impacts of any activity, rather a measure of intrinsic biological value. Therefore, evaluation criteria such as “resilience” and “vulnerability,” which are based on some measure of impact, human value or judgment, are not included in their scheme. They argue that these types of criteria should be considered only after the baseline intrinsic value has been established to answer site-specific questions such as suitable placement for development projects or selection of MPAs.

Derous et al. (2007b) applied the biological valuation method to the Belgian region of the North Sea. Biological value was assessed using valuation criteria, a set of assessment questions for each criterion, and appropriate scoring systems. Examples of assessment questions included:

- Is the subzone characterized by high counts of many species?
- Is the subzone characterized by the presence of many rare species?
- Is the abundance of rare species high in the subzone?
- Is the abundance of habitat-forming species high in the subzone?
- Is the abundance of ecologically significant species high in the subzone?
- Is the species richness in the subzone high?
- Are there distinctive/unique communities present in the subzone?

Derous et al. (2007b) make the point that biological valuation is transparent if assessment questions are objective, clear, and centered on the selected valuation criteria. Valuation should not be done solely using expert judgment as this can lead to subjectivity in the assessment and unrepeatable results. It is critical that any method employing subjective judgments structures these judgments in a manner that enhances replicability (Smith and Theberge, 1987). Detailed assessment questions about "structures and processes of biodiversity" will result in objective valuation whereas assessment questions straying from this theme may result in scoring from one's own perspective, leading to incomparable results among valuations. Selection and development of assessment questions must occur on a case-by-case basis and should be appropriate for that area. Assessment questions are dependent on data availability and the presence of certain processes/structures, etc.

A workshop jointly sponsored by European Network on Coastal Research (ENCORA) and the Marine Biodiversity and Ecosystem Functioning (MARBEF) in 2006 in Ghent, Belgium brought together European researchers and managers to discuss the definition of marine biological valuation, and further developed prototype protocols (i.e., valuation criteria) for mapping and determining intrinsic biological value (as defined by Derous et al., 2007a) (ENCORA/ MARBEF, 2006). The biological valuation criteria identified in Derous et al. (2007a) were discussed at length and re-assessed for future case-study frameworks, renaming the general term "marine biological valuation" to "marine biodiversity valuation" or "marine ecological valuation." The 1st order valuation criteria, which measure biodiversity, were refined to "rarity" (as defined above) and a combined "aggregation-fitness consequences" criterion (Derous et al., 2007c):

- Aggregation-fitness consequences – The degree to which a subzone is a site where most individuals of a species are aggregated for some part of the year; or a site which most individuals use for some important function in their life history; or a site where some structural property or ecological process occurs with exceptionally high density; or the degree to which a subzone is a site where the activity(ies) undertaken make a vital contribution to the fitness (i.e., increased survival or reproduction) of the population or species present (DFO, 2005; Derous et al., 2007c).

Naturalness was excluded from the framework all-together, as the natural state of most waters is unknown and it is difficult to define and apply naturalness without reference to human impact. It was decided that naturalness, or measures thereof, should be assessed after the biological valuation process is completed. Instead of keeping "proportional importance" as a modifying criterion, it was decided that the valuation should be carried out in two ways: at a local scale and at a broader (eco-regional) scale (Derous et al., 2007c).

The Massachusetts Ocean Management Plan (MOP) developed the Ecological Valuation Index (EVI) for Massachusetts state waters (EOEEA, 2009). The EVI was defined as the "numerical representation of the intrinsic ecological value of a particular area, excluding social and economic interests" (EOEEA, 2009). This approach employed spatial analysis techniques where ecological data were gridded into 250 by 250 meter cells. Spatial interpolation was used to fill gaps where data did not exist, resulting in representative surfaces for each ecological entity. Ecological data assessed included presence/absence of species, habitat areas, critical habitats, seafloor characteristics, and fisheries. In this approach, spatial ecological data were evaluated under four criteria adapted from Derous et al. (2007a,b,c,): major contribution to fitness, spatial rarity, population of global importance, and population of regional importance. A set of assessment questions was developed under each of these criteria (i.e., for major contribution to fitness: Does this area make a major contribution to the survival and/or reproduction of the species or population?). A simple binary scoring technique was applied to the data for each of the four criteria. Once data layers were compiled, scores were summed in each grid cell to calculate an overall mapped spatial index, which ranged from low value to high value. However, one of the main limitations of this approach was that the simple binary scoring and summing was insufficiently discriminating of the relative values of the spatial domain, leading to ambiguous results.

A marine ecosystem-based management model was applied to spatially-explicit planning for wind farm development in the sounds and off the coast of North Carolina (Peterson, 2009). The factors involved in this modeling included analysis of 1) spatial distribution of available wind power; 2) ecological risks and synergies, especially for birds and bats; 3) conflicts affecting site selection, such as military uses, ocean shipping lanes, fishing grounds, oyster reef sanctuaries, seagrass beds, and live bottom reef habitats; 4) foundation systems that would be used; 5) geological framework of the area; 6) utility transmission infrastructure; 7) utility-related statutory and regulatory barriers; 8) legal framework, issues and policy concerns; 9) carbon reduction potential, and 10) economics. For the analysis of ecological risks and synergies, birds and bats were assumed to be at greatest risk from wind turbines over water; however, marine mammals, sea turtles, fish, and bottom-dwelling invertebrates were considered due to the potential of harm by noise and other factors. The model also highlighted positive environmental outcomes in some areas from the placement of wind turbines, including oyster reef establishment in saline sounds, rocky-hard bottom creation in coastal ocean, aiding mariculture offshore, and enhancing local upwelling in the coastal ocean.

As the synthesis component of the model, the data from the individual groups were integrated into a geographic information system. While synthesizing the data, the identification of severe constraints that could preclude wind energy development was emphasized. Those areas that were considered "no-build" (e.g., too shallow or reserved for other uses) and those areas with high ecological impact or low suitability for foundation construction were eliminated. For this model, the researcher equally weighed each constraint and assumed an equal degree of certainty to the extents of each component (Peterson, 2009).

5.0 CONCLUSIONS

Based on the existing literature discussed above, we found the biological valuation metrics developed by Derous et al. (2007a,b,c) to be the most scientifically-based, transparent approach, which the least bias in application. Their valuation methodology provides an integrated view of “the intrinsic value of marine biodiversity, without reference to anthropogenic use” and purposefully does not include the socio-economic valuation or quantification of goods and services. Additionally, biological valuation methods developed by Derous et al. (2007a) do not give information on potential impacts of any activity, rather a measure of intrinsic biological value. They argue that criteria such as “resilience” and “vulnerability” should be considered only after the baseline intrinsic value has been established to answer site-specific questions such as suitable placement for offshore development projects or selection of MPAs.

6.0 LITERATURE CITED

Agardy, T. 2010. Ocean Zoning: Making Marine Management More Effective. Earthscan Ltd., London.

Arrow, K., Solow, R., Portney Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R., and Schuman, H. 2001. Report of the NOAA Panel on Contingent Valuation – January 11, 1993. US Department of Commerce, National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program, Silver Spring, MD.

Ball, I.R., and Possingham, H.P. 2000. MARXAN (V1.8.2): Marine reserve design using spatially explicit annealing, a manual. University of Queensland, Australia.

Brody, S.D. 1998. Evaluating the role of site selection criteria for marine protected areas in the Gulf of Maine. Gulf of Maine Marine Protected Areas Project Report 2.

Connor, D.W., Breen, J., Champion, A., Gilliland, P.M., Huggett, D., Johnston, C., Laffoley, D., Lieberknecht, L., Lumb, C., Ramsay, K., and Shardlow, M. 2002. Rationale and criteria for the identification of nationally important marine nature conservation features and areas in the UK. Peterborough, Joint Nature Conservation Committee (on behalf of the statutory nature conservation agencies and Wildlife and Countryside Link), Defra Working Group on the Review of Marine Nature Conservation.

Convention on Biological Diversity (CBD). 2008. Report on the expert workshop on ecological criteria and biogeographic classification systems for marine areas in need of protection. SBSTTA 13th Meeting, Rome, 18-22 February 2008. 25p.

Degraer, S., Verfailie, E., Willems, W., Adriaens, E., Van Lanker, V. and Vincx, M. 2008. Habitat suitability modeling as a mapping tool for macrobenthic communities: an example from the Belgian part of the North Sea. Continental Shelf Research 28(3): 369-379.

De Groot, R.S., Wilson, M.A., and Boumans, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393–408.

Derous, S., Agardy, T., Hillewaert, H., Hostens, K., Jamieson, G., Lieberknecht, L., Mees, J., Mouleart, I., Olenin, S., Paelinckx, D., Rabaut, M., Rachor, E., Roff, J., Stienen, E.W.M., Van der Wal, J.T., Van Lancker, V., Verfaillie, E., Vincx, M., Weslawski, J.M., and Degraer, S. 2007a. A concept for biological valuation in the marine environment. Oceanologia 49(1): 99-128.

Derous, S., Verfaille, E., Van Lancker, V., Cortens, W., Steinen, E.W.M., Hostens, K., Mouleurt, I., Hillewaert, H., Mees, J., Deneust, K., Deckers, P., Cuvelier, D., Vincx, M., and Degraer, S. 2007b. A biological valuation map for the Belgian part of the North Sea: BWZee Final Report. Belgian Science Policy, Brussels, Belgium.

Derous, S., Austen, M., Claus, S., Daan, N., Dauvin, J.C., Deneudt, K., Depestele, J., Desroy, N., Heessen, H., Hostens, K., Husum Marboe, A., Lescrauwaet, A.K., Moreno, M.P., Mouleart, M., Rees, H., Ressurreicao, A., Roff, J., Talhadas Santos, P., Speybroeck, J., Stienen, E.W.M., Tatarek, A., Hofstede, R.T., Vincx, M., Zarzycki, T., and Degraer, S. 2007c. Building on the concept of marine biological valuation with respect to translating it to a practical protocol: Viewpoints derived from a joint ENCORA-MARBEF initiative. Oceanologia 49(4): 1-8.

Douvere, F. 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Marine Policy 32: 762-771.

ENCORA/MARBEF. 2006. Workshop on Marine Biological Valuation: Workshop Report. Ghent, Belgium.

Executive Office of Energy and Environmental Affairs (EOEEA), Commonwealth of Massachusetts. 2009. Volume 2: Development of an Ecological Valuation Index for the Massachusetts Ocean Management Plan. Draft Massachusetts Ocean Management Plan (MOP), Boston, MA.

Fisheries and Ocean Canada (DFO). 2005. Identification of ecologically and biologically sensitive areas. Ecosystem Status Report 2004/006, DFO Canada Science Advisory Section, Ottawa, Ontario, Canada.

Freeman, A.M., III. 1993. The measurement of environmental and resource values: Theory and methods. Resources for the Future, Washington, DC.

French McCay, D., Schroeder, M., Graham, E., Reich, D., and Rowe, J. 2011. Ecological Value Map for the Rhode Island Ocean Special Area Management Plan 2010. Applied Science Associates, Inc. Technical Report in support of the Rhode Island Ocean Special Area Management Plan, University of Rhode Island, Kingston, RI.

Greene, J.K., Anderson, M.G., Odell, J., and Steinberg, N. (eds.). 2010. The Northwest Atlantic Marine Ecoregional Assessment: Species, Habitats and Ecosystems. Phase One. The Nature Conservancy, Eastern U.S. Division, Boston, MA.

International Maritime Organization (IMO). 2006. Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas. Resolution A. 982(24) adopted on 1 December 2005 (Agenda item 11), 13 pp.

Klein, C.J., Steinback, C., Scholz, A.J., and Possingham, H.P. 2008. Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California. Conservation Letters 1: 44-51.

Kopp, R.J., and Smith, V.K. 1993. Valuing natural assets: The economics of natural resource damage assessment. Resources for the Future, Washington, D.C.

Leslie, H., Ruckelshaus, M., Ball, I. R., Andelman, S., and Possingham, H. P. 2003. Using siting algorithms in the design of marine reserve networks. Ecological Applications 13(1), Supplement 2003, S185-S198.

Li, H. 2006. The impacts and implications of the legal framework for sea us planning and management in China. Ocean & Coastal Management 49: 717-726.

Lieberknecht, L.M., Carwardine, J., Connor, D.W., Vincent, M.A., Atkins, S.M., and Lumb, C.M. 2004. The Irish Sea Pilot—Report on the Identification of Nationally Important Marine Areas in the Irish Sea. JNCC, Peterborough, UK.

McLeod, K., and Leslie, H. 2009. Why ecosystem-based management? In: Ecosystem-Based Management for the Oceans, pp. 3-6 McLeod, K., and Leslie, H., (eds.), Island Press, Washington, DC.

Notarbartolo di Sciara, G., and Agardy, T. 2009. Draft interim report to the RAC/SPA: Identification of potential SPAMIs in Mediterranean Areas Beyond National Jurisdiction. Contract no. 01/2008_RAC/SPA, High Seas.

Nijkamp P., Rietveld, P., and Voogd, H. 1990. Multicriteria Evaluation in Physical Planning. Holland Publishers, Amsterdam.

NOAA. 1992. Report of the NOAA Panel on Contingent Valuation. Damage Assessment and Restoration Program, US Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD.

NOAA. 1995. Habitat equivalency analysis: an overview. Damage Assessment and Restoration Program, US Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD.

Nunes, P.A.L.D., and van den Bergh, J.C.J.M. 2001. Economic valuation of biodiversity: sense or nonsense? Ecological Economics 39: 203-222.

Peterson, C. 2009. Spatially explicit ecosystem-based management of wind farm development to minimize use conflicts and maximize energy production and ecological synergies: a North Carolina (USA) example for Pamlico and Albemarle Sounds and the coastal ocean. Ronald C. Baird Sea Grant Science Symposium: The Ecology of Marine Wind Farms, Newport, RI, November 2009.

Possingham, H.P., Ball, I.R., and Andelman, S. 2000. Mathematical methods for identifying representative reserve networks. In: Quantitative Methods for Conservation Biology, pp. 291-305. Ferson, S., and Burgman, M., (eds.), Springer-Verlag, NY.

Richardson, E.A., Kaiser, M.J., Edwards-Jones, G., and Possingham, H.P. 2006. Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data. Conservation Biology 20(4): 1191-1202.

Roberts, C.M, Andelman, S., Branch, G., Bustamante, R.H., Castilla, J.C., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., and Lubchenco, J. 2003a. Ecological criteria for evaluating candidate sites for marine reserves. Ecological Applications 13(1) Suppl.: 199-214.

Roberts, C.M., Branch, G., Bustamante, R.H., Castilla, J.C., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., McArdle, D., Ruckelshaus, M., andWarner, R.R. 2003b. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications 13(1) Suppl.: 215-228.

Smith, R.J., Eastwood, P.D., Ota, Y., and Rogers, S.I. 2009. Developing best practice for using Marxan to locate Marine Protected Areas in European waters. ICES Journal of Marine Science 66: 188-194.

Smith, V.K. 1996. Estimating Economic Values for Nature: Methods for Non-market Valuation. Edward Elgar, Cheltenham, UK.

Smith, P. G. R. and Theberge, J. B. 1987. Evaluating natural areas using multiple criteria: theory and practice. Environmental Management 11(4): 447-460.

Smith, P. G. R. and Theberge, J. B. 1986. A review of criteria for evaluating natural areas. Environmental Management 10: 715-734.

Stewart, R.R., Noyce, T., and Possingham, H.P. 2003. Opportunity cost of ad hoc marine reserve design: an example from South Australia. Marine Progress Series 253: 25-38.

Unsworth, R.E., and Bishop, R.C. 1994. Assessing natural resource damages using environmental annuities. Ecological Economics 11(1): 35-41.

Villa, F., Tunesi, L., and Agardy, T. 2002. Zoning marine protected areas through Spatial Multiple-Criteria Analysis: the case of the Asinara Island National Marine Reserve of Italy. Conservation Biology 16(2): 515-526.

Voogd, H. 1983. Multicriteria Evaluation for Urban and Regional Planning. Pion Ltd., Amsterdam.

Ward, T.J., Vanderklift, M.A., Nichols, A.O., and Kenchington, R.A. 1999. Selecting marine reserves using habitats and species assemblages as surrogates for biological diversity. Ecological Applications 9(2): 691-698.

Watts, M.E, Ball, I.R., Stewart, R.R., Klein, C.J., Wilson, K., Steinback, C., Lourival, R., Kircher, L., and Possingham, H.P. 2009. Marxan with Zones: software for optimal conservation based land- and sea-use zoning. Environmental Modelling & Software 24(12): 1513-1521.

Wilson, E.O., (ed.). 1988. Biodiversity. National Academy Press, Washington, DC.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.

www.boem.gov