Ocean Special Area Management Plan
Science Research Agenda
June 13, 2012

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Executive Summary

With the State's adoption of the Ocean Special Area Management Plan (SAMP) as the primary planning and management document for offshore development, Rhode Island has moved to the forefront of marine spatial planning in the United States. The purpose of the Ocean SAMP Science Research Agenda is to identify where additional research is needed and recommend approaches for filling these knowledge gaps.

The objectives of this report are to:

- Continue to learn about Rhode Island's offshore natural resources and human activities;
- Better understand the potential effects of future development, including offshore wind energy, and other human impacts;
- Increase Rhode Island's understanding of the projected impacts of global climate change;
- Guide scientifically sound management decisions and support adaptive management strategies to minimize impacts to the environment;
- Promote the efficient development of renewable energy facilities where feasible; and
- Identify areas for collaboration and multidisciplinary projects.

The agenda was created with contributions from Ocean SAMP researchers, state and federal government agencies, environmental organizations, the public, and other stakeholders, including the fishing, recreation, and tourism industries. The development process was transparent, involving parties through questionnaires, as participants in meetings, and as document reviewers.

The research proposed focuses on:

- **Baseline data**. Collecting baseline data will permit further characterization of current ecosystem patterns and processes, including environmental conditions and biological distribution, abundance, and habitat use patterns.
- **Monitoring**. Monitoring to assess impacts due to offshore development and climate change. Assessment involves the identification and evaluation of the range and magnitude of potential effects associated with development or climate change on natural resources and human activities.
- **Advancing ocean engineering of offshore renewable energy devices**. Establishing appropriate design, construction, and structural requirements is essential to ensure an offshore energy facility reaches its maximum potential and efficiency.
- **Developing an information framework**. An information framework is a necessary component to organize, visualize, analyze, and disseminate information in a manner that is useful to researchers, regulators, developers, and the public.

These focus areas would greatly benefit our understanding of the Ocean SAMP ecosystem over various spatial and temporal resolutions, and allow for relationships and trends within the ecosystem to be examined.

While the research agenda focuses on the waters of the Ocean SAMP study area, the research ideas expressed may be applicable for regional marine spatial planning efforts or valuable on a national scale as it relates to understanding the effects of offshore renewable energy development.

1.0 Introduction

The Ocean Special Area Management Plan (Ocean SAMP) process and resulting document has afforded Rhode Island local and national attention in the fields of marine spatial planning and offshore renewable energy (ORE) development. The success of the Ocean SAMP was its ability to accomplish extensive research goals and fully engage stakeholders throughout the 2-year process. Since the completion of the Ocean SAMP, Rhode Island has continued to lead the way, further working to overcome the scientific and management challenges related to offshore development both at local and national scales.

Prior to the Ocean SAMP there was limited knowledge regarding the natural resources and human uses of Rhode Island's offshore waters. The Ocean SAMP process addressed this knowledge gap through the compilation and synthesis of existing information and the collection of new data. While a large amount of new data was collected, additional research is still needed to further characterize baseline conditions and patterns within the Ocean SAMP area (Figure 1), as well as to assess impacts from ORE development and climate change at appropriate spatial and temporal scales.

This need for additional research was recognized in the Ocean SAMP document (Section 1130. Applying Adaptive Management to Implement the Ocean SAMP):

> "CRMC will develop and implement the Ocean SAMP Science Research Agenda, in coordination with the Ocean SAMP researchers, federal, state, and local government and other parties, to improve management policies and practices. The Ocean SAMP Science Research Agenda will allow CRMC to: 1) Continue to learn about Rhode Island's offshore natural resources and human activities; 2) Better understand the potential effects of future development and other human impacts; and 3) Increase Rhode Island's understanding of the projected impacts of global climate change. To develop the Science Research Agenda, the Council will put together an advisory group including scientists, partner federal and state agencies, environmental organizations, and users of the Ocean SAMP area. This group will help the Council to identify data gaps, short- and long-term research priorities, potential partners, and potential funding sources."

The Science Research Agenda is one mechanism to ensure the Ocean SAMP is implemented using an adaptive management approach. Adaptive management has been the strategy undertaken by the Coastal Resources Management Council (CRMC) to manage Rhode Island's coastal waters since its inception in 1971. Adaptive management is a systematic process for continually improving the management of an area by learning from the outcomes of previously employed policies and practices. Adaptive management requires careful implementation, monitoring, evaluation of results, and adjustment of objectives and practices.

This research agenda has been created to identify topic areas where additional study is still needed. Specifically, the objectives of this research agenda are to:

- Identify topics that require further investigation in order to better understand existing natural environment and human uses of the Ocean SAMP area;
- Outline research needed to assess the impact of offshore development, including offshore wind energy, and the impact of climate change;
- Assist in obtaining and directing future fundraising opportunities; and
- Identify areas for collaboration and multidisciplinary projects.

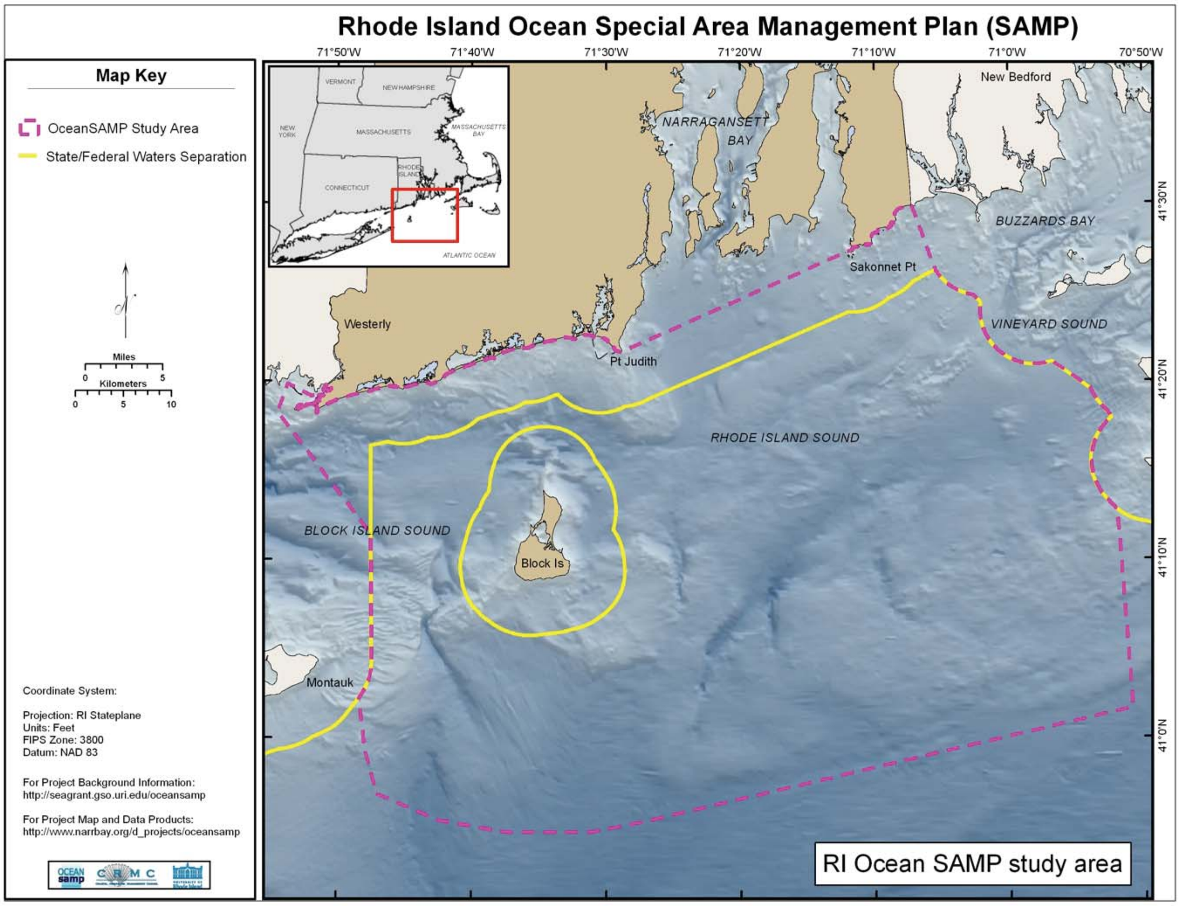

Figure 1. Rhode Island Ocean Special Area Management Plan (Ocean SAMP) study area.
The study area encompasses Rhode Island and Block Island Sounds and is approximately 1,500 sq mi.

The research needs presented in this agenda were identified by the researchers involved in the Ocean SAMP process, Rhode Island's Habitat Advisory Board and Fishermen's Advisory Board, as well as contributions from environmental organizations, stakeholders, and the public.

This research agenda begins with a description of projects focused on providing a more complete baseline characterization for either the entire Ocean SAMP study area or particular portions of the study area (Section 2.0). The purpose of this research is to increase understanding of current conditions, resources, and human uses. To aid in directing research funding, section 2.0 prioritizes the research goals according to location: the entire Ocean SAMP study area, the Renewable Energy Zone (REZ), and the Area of Mutual Interest (AMI). Section 3.0 discusses projects aimed at assessing the effects of ORE development, during both construction and operation, and of climate change. Inherently, these projects will also rely on the baseline data collected as part of the Ocean SAMP and outlined in Section 2.0. Section 4.0 summarizes research related to ocean engineering, dealing with offshore design, construction, and structural concerns. Section 5.0 presents requirements for developing a framework to effectively organize, visualize, and distribute information. Lastly, Section 6.0 discusses how this Ocean SAMP research agenda may relate to other regional research initiatives such as the Northeast Regional Ocean Council (NROC) or the Northeast Sea Grant Consortium.

With the State's adoption of the Ocean SAMP as the primary planning and management document for offshore development, Rhode Island has moved to the forefront of marine spatial planning in the United States. The Ocean SAMP research agenda presents the opportunity for Rhode Island to further lead the way in offshore wind energy and oceanographic research and work towards establishing a standardize framework to organize, collect, analyze, and communicate research between and among scientists, managers, and the public. The ultimate goals of these projects are to promote the efficient development of ORE facilities and guide scientifically sound management decisions to minimize environmental impacts while maximizing economic benefits. Although this document focuses on Rhode Island waters, the recommendations expressed are applicable for marine spatial planning and ORE development efforts at other locations.

2.0 Research Focused on Baseline Data Collection

The research proposed below in sections 2.1 – 2.12 would greatly benefit our understanding of the Ocean SAMP ecosystem by providing the opportunity to further characterize baseline environmental conditions and biological distribution, abundance, and habitat use patterns. While proposed on a local scale (the Ocean SAMP study area), the data needs described below are presented for the consideration of any planning efforts, regardless of study location, to guide science and management actions.

Baseline studies involve the collection of data to understand the current state of the ecosystem (environmental and biological attributes). Often this work is undertaken before a project, such as ORE development, is initiated or to obtain a starting point. The baseline conditions can then be used as a point of reference against which to compare subsequent data.

Baseline studies should be sustained over multiple years; this time frame is needed because substantial inter-annual variability has already been documented in nearly all processes and system attributes within the Ocean SAMP area. Having long and detailed baseline data sets are valuable for detecting and explaining natural and human-induced variability in ecosystem patterns and processes over various spatial (centimeters to kilometers) and temporal (intratidal, seasonal, annual, long-term) resolutions. Consequently, these baselines are essential to researchers for distinguishing between natural variability in the ecosystem and changes due to human disturbance (development, fishing), episodic events (storms, spills), climate change, and anomalies. Understanding baseline conditions is critical for making well-informed, science-based management decisions, particularly those related to marine spatial planning.

For example, as a result of the baseline data collected during the Ocean SAMP process, important habitats, foraging areas, and human use areas were identified and protected as Areas Designated for Preservation (ADPs) and Areas of Particular Concern (APCs) (refer to Ocean SAMP, Chapter 11). Additional baseline data could be used to support the importance of existing ADPs and APCs, or identify additional areas that should be protected from development activities. The Ocean SAMP policies direct potential developers to avoid APCs, and if avoidance is not possible developers must minimize and mitigate any impact to APCs. Current APCs include moraines, due to their high biodiversity, and some recreation and fishing areas, due to their economic, ecological, and/or cultural importance. Alternatively, ADPs prohibit all development activities and currently comprise sea duck foraging habitat.

Multidisciplinary baseline data throughout the Ocean SAMP area naturally fosters collaborations between and among fields, including ecology, biology, fisheries, geology, and physical oceanography. Such data sets would also allow relationships and trends within the ecosystem to be examined. As examples: 1.) Primary production rates and phytoplankton blooms are often influenced by physical oceanographic parameters, such as temperature, stratification, and circulation; 2.) Fish abundance and distribution patterns could be analyzed in conjunction with fishing activity patterns to provide a more complete picture of fisheries in the Ocean SAMP area; and 3.) Obtaining co-located, simultaneous data sets would provide more powerful data sets for resolving relationships. Collaboration is also beneficial logistically, for example, vessel based surveys could be coordinated to achieve various data collection goals while minimizing expenses, time, and personnel. Underwater archeology, for instance, could use much of the same data collected for benthic habitat characterization, physical oceanography, and fisheries studies.

In addition to filling in knowledge gaps, baseline data could also be used to develop models of the Ocean SAMP area. Models are valuable tools, as they 1.) Produce realistic simulations of the system; 2.) Build an understanding of system attributes, patterns, and processes; and 3.) Provide a view of spatial and/or temporal gaps in measurements. For example, with physical oceanography, models offer spatial and temporal understanding of measurements, such as temperature, salinity, and current and circulation pathways. Models can also be used to evaluate fates of waterborne materials (spill trajectories, dispersal patterns, and particle pathways).

A major strength of modeling is the ability to integrate data across disciplines, which could further assist in discerning relationships within the system. For instance, hydrodynamic simulations also serve as the starting point for biogeochemical simulations, which would be useful for understanding the system from an ecological standpoint; and inform other disciplines. Physical oceanography data and model outputs could be valuable for other studies (ecology, habitat, fisheries, and birds) and for deriving relevant ecological parameters (anoxia-hypoxia, stratification, tidally-driven patterns, current patterns). As an example, data collected for the Ocean SAMP report is currently being incorporated into a benthic habitat model.

Well-designed simulations are needed to properly investigate potential changes to the system associated with climate change (e.g. precipitation, river runoff, wind strength, and wind direction) and/or human induced changes (e.g. effects of turbine infrastructure on seasonal cycle of stratification). Furthermore, models make possible investigations of hypothetical scenarios to predict how change (human impact, climate) might alter an environment. To evaluate change, simulations with realistic forcing are compared to those with artificially modified forcing; models are executed under different scenarios by adjusting the input parameters to examine how the system would respond and the potential magnitude of the response. Therefore, modeling and change scenarios permit researchers to address specific questions about the system, such as those regarding human use, storm events, climate change, and natural ecosystem variation. From a management perspective, models and change scenarios may guide policy decisions to prevent and/or mitigate issues.

The studies proposed below should occur throughout the Ocean SAMP study area within and outside of areas of interest for offshore renewable energy (ORE) projects. Establishing outside "control" sites would allow for comparisons to be made and provide better knowledge of development impacts.

2.1 Observation stations

<u>Establish a series of fixed buoy monitoring stations.</u> Observation stations would act as platforms for co-located *in-situ* acquisition of multidisciplinary data; the types of measurements that could be collected concurrently are shown in Table 1. Profile moorings are suggested, on which a single sensor package moves vertically and samples the entire water column. Profile moorings can capture vertical structure of the water column much more comprehensively, thus providing a better view of processes, including stratification and turbulent overturn characteristics. The data would be collected continuously to achieve high temporal resolution and high spatial resolution of

the water column. Furthermore, profile moorings require only a single sensor package, making them more cost-effective than mounting several sensors at fixed depths.

Table 1. Observation station data potentially acquired through fixed buoys.

	Data
Biological data	Chlorophyll a concentration
	Primary production rate
	Respiration rate
	Fluorescence
	Nutrient concentrations
	Partial pressure CO^2
	Total inorganic carbon (TOC)
	Phytoplankton and zooplankton abundance and distribution
	Food-web interactions
Physical data	Salinity
	Temperature
	Oxygen concentration
	pH
	Density
	Stratification
	Turbidity
	Turbulence
	Surface waves
	Current (speed and direction)
	Wind (speed and direction)
Marine Mammal data	Vocalizations

Observation station locations may include locations where development is proposed, such as the Renewable Energy Zone southeast of Block Island (REZ) and the Area of Mutual Interest (AMI) (Figures 2 and 3, respectively), to assess pre-development environmental condition. In addition, stations should be established at control sites where development is not set to occur for comparison purposes. Control stations should be located enough distance away from ORE sites to allow for the distinction of the effects of ORE development from natural ecosystem variability.

Successful examples of mooring-based efforts include programs in Long Island Sound, Narragansett Bay, and coastal waters (the Northeastern Regional Association of Coastal and Ocean Observing Systems [NERACOOS] and Mid-Atlantic Regional Association Coastal Ocean Observing System [MARACOOS]). These programs have proven influential in both the science and management arenas.

Importance

Establishing a series of fixed-buoy stations to collect co-located, multidisciplinary data would greatly benefit scientists and managers. These rich data sets would:

- Provide the opportunity for the Ocean SAMP area to be examined as an ecosystem as a whole, instead of fragmentary;
- Provide high temporal resolution data for baseline characterization of the existing ecosystem, recognizing and understanding change, and performing ecosystem-wide analyses;
- Improve spatial resolution of current data base
- Encourage investigations of relationships between and among different parameters. For example, physical oceanography measurements could assist in recognizing the causation behind primary production patterns witnessed in the Ocean SAMP study area. The great variability in primary production specifically makes the initiation of a longer term, multi-year data acquisition program essential in understanding ecosystem patterns and processes;
- Assist in assessing effects of development on the environment within and outside of infrastructure;
- Complement vessel-based surveys. Observation stations offer data at high temporal resolution, whereas vessel-based surveys offer high spatial resolution;
- Improve understanding of the physical processes driving the Ocean SAMP area and region; and
- Assist in developing and validating any models of oceanographic and climatologic parameters throughout the Ocean SAMP area. The combination of observation station and vessel-based survey data opens the potential for modeling parameters over suitable spatial and temporal scales.

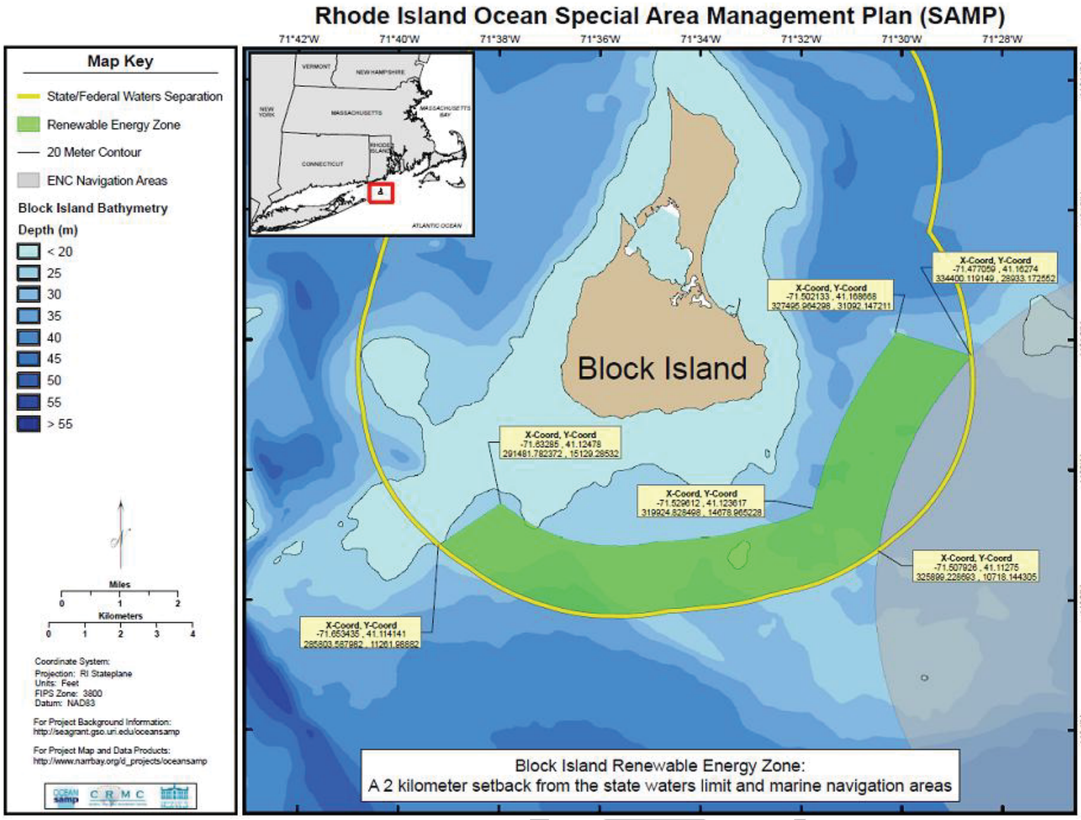

Figure 2. Block Island Renewable Energy Zone (REZ).

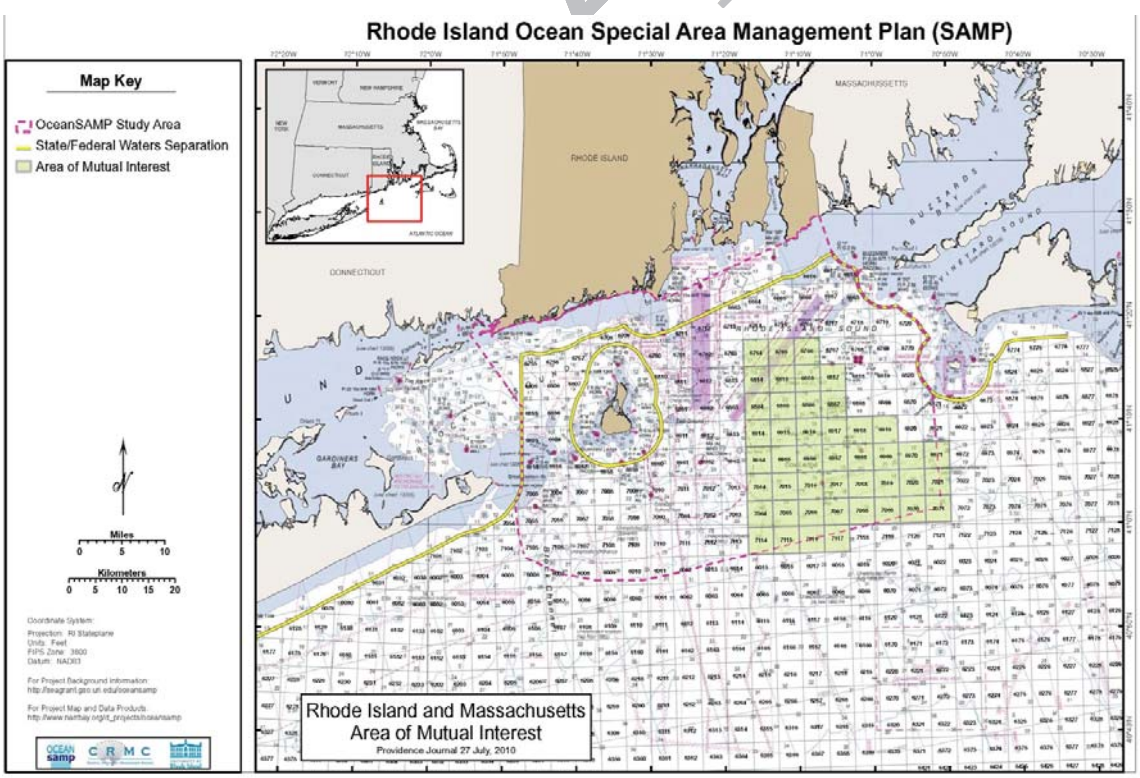

Figure 3. Rhode Island and Massachusetts Area of Mutual Interest (AMI).

2.2 Physical oceanography

Measure physical oceanographic parameters. Parameters to be measured are indicated in Table 1. The methods proposed to achieve this research goal are observation stations and vessel-based surveys. The establishment of a series of fixed buoy monitoring stations would provide high temporal resolution data and is described in section 2.1. Vessel-based surveys performed throughout the Ocean SAMP area would complement observation stations by offering data of higher spatial resolution. Surveys would collect vertical profiles of water properties using a CTD and would be conducted once monthly over a grid of 50-100 locations spanning the Ocean SAMP area. In addition, data could be collected off of the Block Island ferry; the ferry would be equipped with an ADCP to collect long duration repeat transect time series of vertical profiles of currents. The ferry could also carry nutrient and water quality sensors. Examples of similar vessel-based survey monitoring efforts, and their invaluable contributions to science and management programs, can be seen in Long Island Sound (Connecticut Department of Environmental Protection) and Narragansett Bay (Brown University; Atlantic Ecology Division of the US Environmental Protection Agency); these programs form a guide, for example regarding the kind of station spacing and survey frequency that would be most effective.

Develop physical oceanography models. Create a hydrodynamic/biogeochemical models to produce realistic simulations of the Ocean SAMP system. The user could then configure the input parameters (e.g. wind, temperature, salinity, transport rates, currents) and execute the model under different change scenarios to evaluate the system's reaction.

Importance

The proposed physical oceanography data collection program is essential to:

- Characterize spatio-temporal patterns within the Ocean SAMP domain, with emphasis on full water column structure;
- Establish baseline conditions. It is recognized there is considerable variability of physical processes, such as current and circulation patterns, within the Ocean SAMP area, including inter-annually. Therefore, a long-term data collection program is needed to discern inter-annual trends and anomalies from climate change impacts;
- Recognize driving factors (e.g. wind forcing, estuarine exchange, shelf interactions, and tidal processes) behind observed variability and trends;
- Define circulation and transport pathways, including exchanges with nearby estuaries (Long Island Sound, Narragansett Bay) and the outer shelf, and exchanges between key constrictions (Point Judith and Block Island, Block Island and Montauk Point);
- Determine volume and rates of water transport;
- Identify budgets for water and abiotic/biotic water-borne materials; and
- Develop models and change scenarios.

2.3 Wind and climatology

The unique combination of Rhode Island's water climatic and oceanographic conditions requires coupled monitoring of the wind field and sea-state. Such data would allow an accurate estimate the wind resource, and consequently optimize wind farm development within the Ocean SAMP area in terms of geographic location and footprint scale. To accomplish this goal, the following tasks should be undertaken:

Quantify the wind resource. The wind resource, outside the area of influence of the wind farm, can be represented by the mean wind speed distribution. An accurate estimation of the mean wind field can provide an accurate estimation of the expected power output from a single turbine at a specific location. However, the current spatial uncertainty in the wind field, in particular in the proximity of islands (such as Block Island), as well as vertical profile uncertainties, lead to potential expected power uncertainty, maybe as large as 30 % at hub height. Spatial and vertical monitoring of the mean wind field must be refined at the local scale using state of the art monitoring techniques, such as a floating (upward looking) LIDAR able to scan the vertical structure of the lower atmospheric boundary layer at a relevant vertical (up to 200 m in elevation) and spatial scale (order 200 m horizontal grid to validate AWS true wind model data).

Quantify complex airflow fields induced by a wind farm and the feedback on the wind field. Accurately estimating the extracted power from an offshore wind farm requires an assessment of the wind field between turbines. Since each turbine interacts with the incident wind field, the wind field between turbines is modified and becomes far more complex than the undisturbed wind field outside of the wind farm. Accurately assessing this "inter-turbine" wind field requires complex modeling of interactions between the wind resource, turbines, boundary layer, and sea surface interactions (Moriarty, 2012). Such a model should be applied to the Ocean SAMP area, and in particular to the REZ, in order to assess the truly extractable power in Rhode Island's offshore environment.

Importance

The proposed wind and climatology research is valuable to:
- Accurately define and predict the theoretical wind resource provided by the environment;
- Accurately define and predict the extractable wind resource in a wind farm; and
- Examine spatial and temporal variability of wind resource.

2.4 Benthic habitat

Mapping of priority areas. The Ocean SAMP focused on high-resolution mapping of areas identified as priorities for potential offshore wind development. This effort should continue in areas of high priority, as mapping provides valuable visual information of the geospatial distribution patterns and processes of numerous marine resources. The mapping process involves the collection (via vessel-based surveys) and integration of high-resolution geophysical data (side-scan sonar, bathymetry, and sub-bottom seismic reflection profiles) and ground-truth data (sediment and biology samples, underwater video and photography, sediment profile imagery). The types of maps that could be created are presented in Table 2.

Table 2. Potential maps to be developed from future mapping projects.

Map	Purpose
Quaternary geologic depositional environment	Present distribution patterns and extent of subsurface sediment characteristics, including the existence and thickness of stratified deposits (i.e. glacial lakefloor) and Holocene (marine) deposits. Identify extent and distribution of moraines (recognized as Areas of Particular Concern in the Ocean SAMP process)
	Help understand sediment transport and deposition processes
Biological communities/ species	Present distribution patterns and abundance of biological communities or species of interest
Benthic habitat	Examine and classify biological-environmental relationships through integration of data (e.g. benthic biology, water depth, depositional environments). Accomplished through statistical analyses. Good relationships between benthic geologic and biologic characteristics have been found previously within the Ocean SAMP area (LaFrance et al., 2010) (Figure 4)
	Present distribution patterns and extent of biologic-geologic characteristics of seafloor environments (Auster et al., 2009)
	Identify geological feature, biological communities/species of interest
Mobile fishing gear use	Identify locations utilized by finfish and shellfish trawlers from trawl scars visible in side-scan sonar records
	Provide use-intensity information
Cultural and historical resources (e.g. shipwrecks)	Survey data could lead to the discovery of unknown resources or confirm the location of known resources
	Aid in documenting fishing activity to identify important commercial and recreational fishing grounds

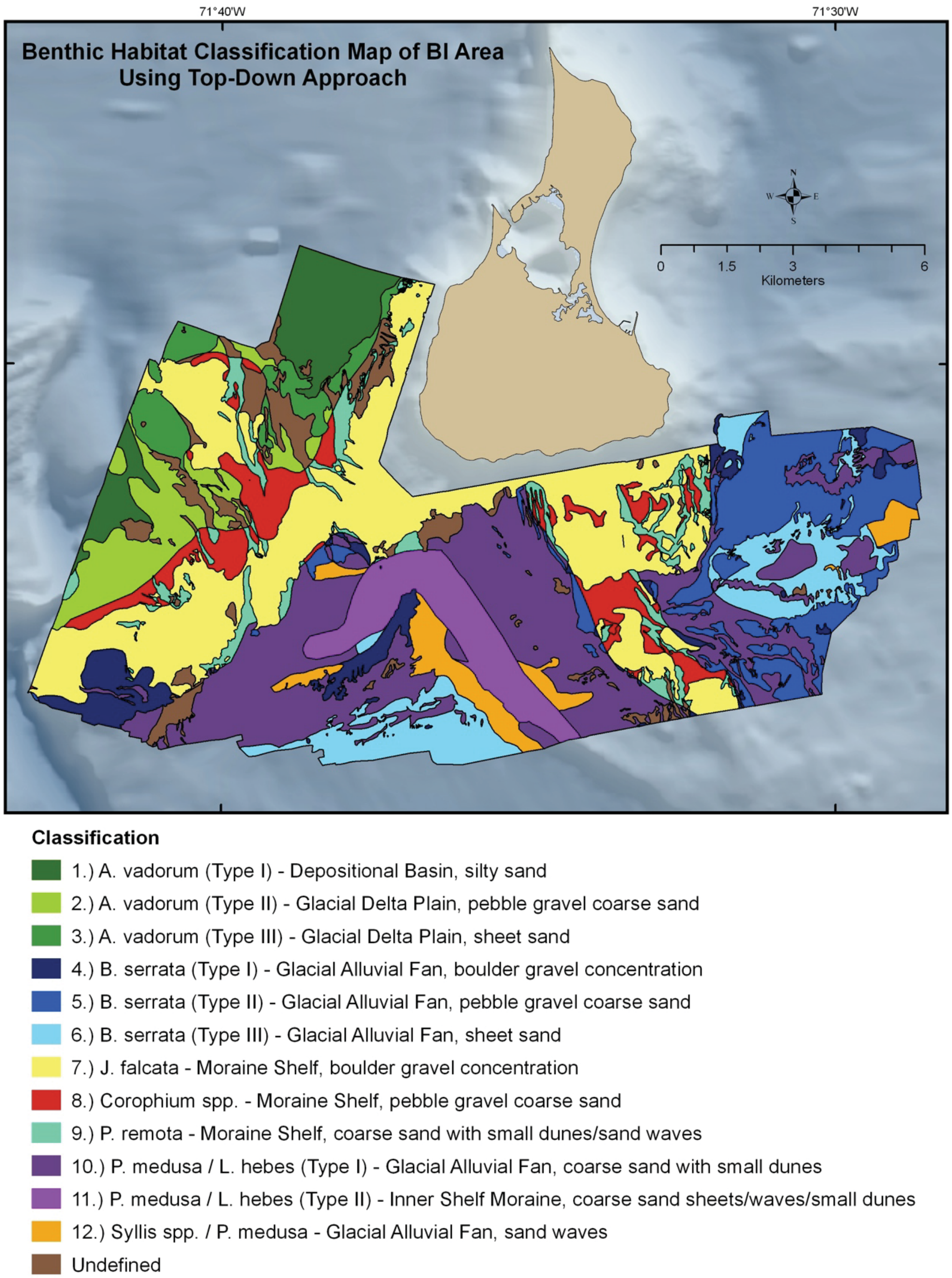

Figure 4. Classification map of habitats offshore of Block Island. (From LaFrance et al., 2010, Ocean SAMP Technical Report 4). Each map unit, as defined by Quaternary geologic depositional environment type, is classified according to the most abundant genus. Environmental-biologic relationships were determined statistically.

Continue to improve habitat template and ecosystem services typology models. It is not feasible (due to cost and time) to map the entire Ocean SAMP area at the resolutions required for micrositing analyses and pre-permitting assessments; therefore, for broad scale characterizations, models must be developed and validated to provide information of the benthic ecosystem. The habitat template method (Kostylev and Hannah, 2007) is a model that uses measures of natural disturbance and physiological stress to estimate species diversity and community composition. These measures are modeled using broad-scale Ocean SAMP-area-wide datasets, including bathymetry, chlorophyll, and frictional velocity. The model is currently based on multivariate statistical analysis, will be updated with a neural network approach. These models would provide full coverage maps of the Ocean SAMP area and would be effective tools for understanding the dynamic of the ecosystem. In particular, they may be used to inform micrositing, monitoring plans, and to model changes in diversity, resulting from shifts in any of the model variables.

Validate and refine models. The habitat template and ecosystem services typology models must undergo extensive testing to confirm their predictions. A cross-validation of the models that shows similar results between the two will confirm that they are robust. Validation could also be achieved by testing model results against actual data obtained from the Ocean SAMP process (including benthic macrofauna and fish sampling, underwater video, acoustic imagery; LaFrance et al., 2010, Malek et al., 2010), and from the collection of new data.

Develop indicators of seafloor disturbance. Indicators of seafloor disturbance could be species-based, community-based, or based on abiotic variables. Indicator development involves establishing baselines and expected biological responses, as has been done in Europe (Andrade et al., 2011, Rice et al. 2012) using current benthic sampling techniques. Indicators would be useful in the future for rapidly assessing the magnitude of impact at any stage of any project and for comparing the impacts of a wide range of coastal disturbances (oil and gas exploration, fishing, renewable energy projects) in the SAMP area and regionally.

Importance

The proposed mapping research could direct future studies and guide management decisions, as it has the ability to:

- Provide baseline classification of habitats within the Ocean SAMP area against which to measure change over various temporal and spatial scales;
- Identifying features (geologic, fishing trawl scars, shipwrecks), critical use areas (essential fish habitat, foraging and nursery grounds, valuable fishing grounds), and areas of biologic importance (sensitive, high biodiversity, target biological communities or species) in need of further examination or that warrant protection from human disturbance;
- Identify Areas of Particular Concern (APC), such as moraines and other features with coarse-grained (gravel or larger) sediment;
- Use data, including APCs to direct construction locations by indicating where installation would be easiest and least expensive. For example, on Stellwagen Bank, geologic maps were used to plan a fiber-optic cable route, avoiding gravelly geologic habitats where the cable could not be buried for its protection. In addition, knowing the sub-surface depth to unstratified glacial deposits (till) and the semi-

consolidated Cretaceous-Tertiary age strata could provide information about how turbines would need to be installed (pile-driving, drilling);

- Provide powerful modeling tools to aid in micrositing, monitoring, to examine potential impacts of changes to the ecosystem due to environmental and anthropogenic factors (e.g. construction, climate change, storm activity), and to identify spatial scales at which impacts are expected to occur; and
- Rapidly assess and compare the magnitude of impact of human disturbances using indicators of seafloor disturbance.

2.5 Ecology

Measure ecological parameters. Data of interest are listed in Table 1 and includes primary production and respiration rates, nutrient concentrations, and phytoplankton and zooplankton dynamics. Data would be collected at observation stations and during vessel-based surveys using instruments such as plankton samplers, nutrient sensors, and optical sensors. The establishment of a series of fixed buoy monitoring stations would provide high temporal resolution data and is described in section 2.1. Vessel-based surveys conducted throughout the Ocean SAMP area would complement observation stations by offering data of higher spatial resolution. It is recommended these surveys occur once per month.

Develop models. Primary production and chlorophyll *a* measurements could be used to ground truth modeled results within the Ocean SAMP area derived from satellite imagery. Once the relationship between the two methods (*in situ* measurements and satellite data) has been established, satellite imagery could be used to increase spatial resolution of primary production measurements.

Measure benthic community organic matter consumption and nutrient regeneration. These measurements for the Ocean SAMP project were confined to areas of fine-grained sediments. However, sandy coarse-grained sediments dominate most of the Ocean SAMP area and organic matter consumption and nutrient regeneration cannot be measured using extracted cores (as done in the fine-grained areas). These sandy sites need to be studied using state of the art eddy correlation techniques.

Importance

The continuation of primary production measurements is vital in understanding how changes to the ecosystems may effect biological production. As the primary producers of coastal ecosystems, phytoplankton are responsible for supporting the growth of species at various trophic levels through the fixation of carbon and other required nutrients (Durbin et al. 2003; Pershing et al., 2005, Steele, 2001). Phytoplankton are the dominant prey item for zooplankton species and are integral in contributing to benthic-pelagic biogeochemical cycling and feeding benthic infuana as sinking organic matter and detritus (Durbin et al. 2003; Fulweiler et al. 2007; Smith et al. 2010). The timing and extent of the winter-spring phytoplankton bloom has been found to strongly correlate with fish larvae survival and recruitment success (Platt et al. 2003; Head et al. 2005). It is hypothesized that phytoplankton blooms contribute to the success of mature demersal fish by providing food for their prey items in the benthos, enhancing their condition, and permitting them to produce greater quantities and higher quality eggs (Friedland et al. 2008).

The proposed ecological research is necessary to:

- Perform a holistic examination of ecosystem function and biological production of the Ocean SAMP area;
- Produce baselines ecological parameters and their patterns, including primary production rates, organic matter consumption, nutrients, phytoplankton and zooplankton dynamics, and food-web interactions, over various spatial and temporal scales;
- Better understand primary production within the study area. Primary production rates can greatly fluctuate any given season or year depending on ambient conditions. The great variability in primary production specifically makes the initiation of a longer term, multi-year survey of primary production and chlorophyll *a* patterns in the Ocean SAMP area essential for creating a baseline of biological productivity for future management actions;
- Better understand driving forces behind and interactions between observed patterns;
- Calculate total system metabolism (production and respiration) and net air-sea exchange of CO2 from partial pressure of CO2 and total inorganic carbon. This would provide for the first time estimates of the excess production available to support higher level of the food web within the Ocean SAMP area;
- Better understand benthic community organic matter consumption and nutrient regeneration. The balance between the production of organic matter in the sunlit surface waters and the consumption of this organic matter in the water column and on the bottom provides the energetic base for fish and other higher trophic level production. The tight biogeochemical coupling of the water column and the bottom is a characteristic of virtually all coastal systems, though it is generally poorly document and quantified in areas with sandy sediments such as the Ocean SAMP area. The new techniques proposed, however, would provide insight of ecosystem characteristics; and
- Assist in developing and validating models of primary production rates from satellite imagery throughout the Ocean SAMP area.

2.6 Avian

Assess baseline distribution and abundance of avian species. Having additional baseline information about the spatial distribution and abundance of avian species would allow biologists a more detailed understanding of seasonal and annual variation in bird use within the Ocean SAMP study area. These data could also be used to identify key foraging and resting sites, migratory corridors, and important habitats used that should be protected from disturbance. This research should be conducted throughout the year to assess seasonal and annual variation in avian use of the study area. Surveys would be conducted along transects that are placed perpendicular to the avian density gradient (Figure 5; refer to Ocean SAMP Report for further details). Specific methodologies are discussed in Table 3.

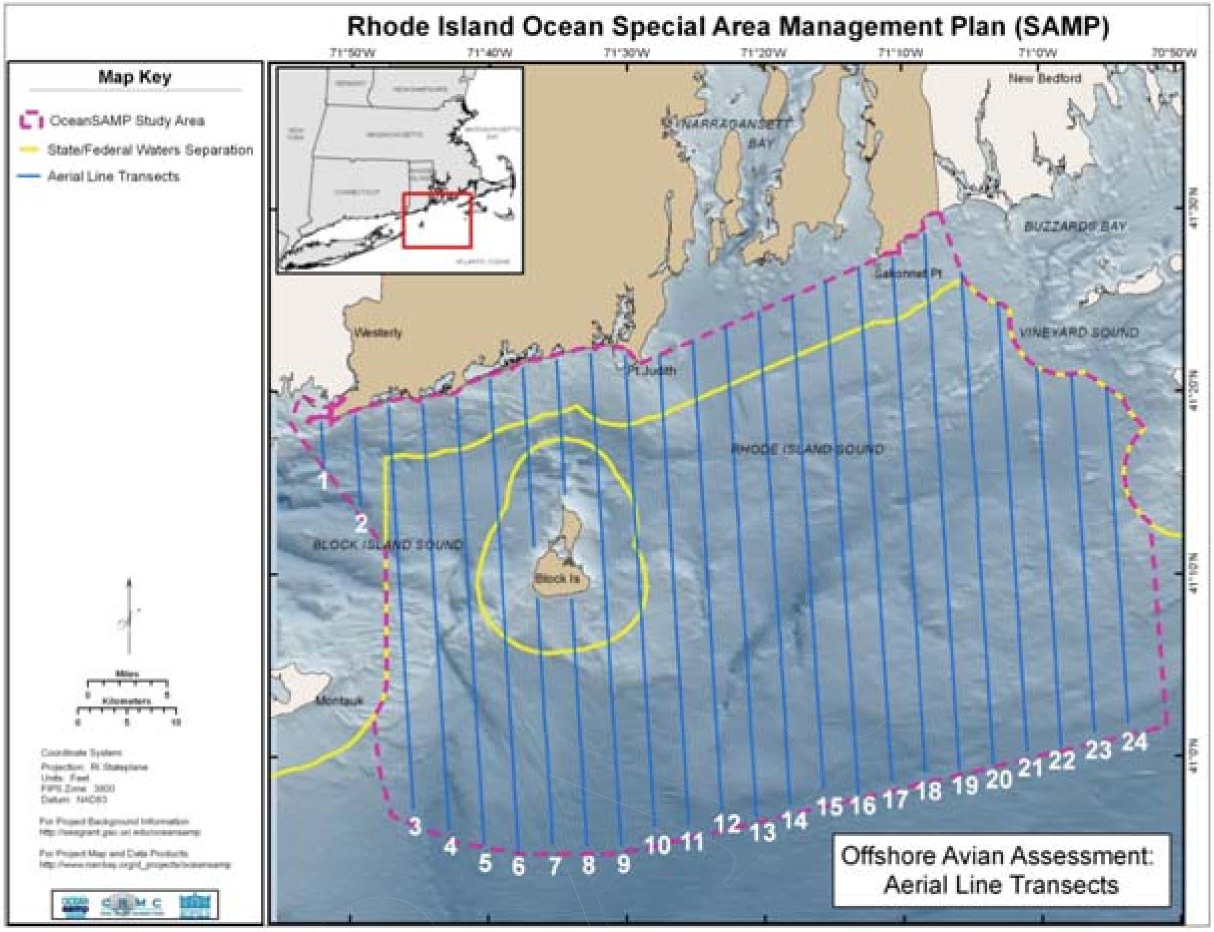

Figure 5. Avian aerial survey transects. (From Winiarski et al., 2011, Ocean SAMP Technical Report 11 addendum). Location of 24 aerial transects sampled from 2009 – 2012.

Examine movement ecology of birds. Little is known about the movement ecology (flight altitudes, phenology of movements, movement direction) of birds in the Ocean SAMP study area, with the exception of satellite telemetry investigations of seaducks. This information could be used to assess barrier effects and develop collision risk models for bird use in the study area. Methodologies to achieve this goal are discussed in Table 3.

Investigate factors affecting variability in avian distribution and abundance patterns. To better understand seasonal and annual variation in the spatial distribution and abundance of birds, information is needed on potential prey (fish, invertebrates, benthic organisms), habitat conditions (benthos, sea surface temperature, chlorophyll, salinity, fronts), and anthropogenic activities (e.g. recreational and commercial fishing, development). Having this data would lead to the development of models of distribution and habitat use patterns of avian species.

Table 3. Methods for characterizing avian use.

Method	Advantages	Execution
Ship-based line transect surveys	• Provides spatially-explicit estimates of density • Allows identification of organisms to species-level, including threatened and endangered species • Access to areas close to Block Island	• Transects similar to baseline studies using standardize protocols • Conducted throughout year to assess seasonal variation • Perpendicular to density gradient • Develop Density Surface Models for study area and adjacent buffer (Before-After- Gradient design) • Studies conducted before construction and up to 10 years after construction
Aerial –surveys (observer or videography)	• Provide coverage over large areas over short time periods • Videography allows permanent record of detections	• Transects similar to baseline studies using standardize protocols • Conducted throughout year to assess seasonal variation • Transects located perpendicular to density gradient • Develop Density Surface Models for study area and adjacent buffer (Before-After- Gradient design) • Studies conducted before construction and up to 10 years after construction
Tagging (radio telemetry, satellite telemetry, GPS, nanotags)	• Offers detailed data of movement ecology individuals • Records movement, and therefore, habitat use	• Tags would be tracked remotely (monitored by satellite, base stations, or directional antenna arrays) • Satellite telemetry would follow ongoing efforts with seaducks in RI • Studies prior to construction and up to 5 years post construction
Land-based Radar	• Provides flight altitudes, flight directions, and number of targets • Only protocol that can collect information on nocturnal migrants • Determine barrier effects and model collision risk	• Use a combination of vertical and horizontal X-band marine radar units • Operate 24 hrs per day 7 days per week, both pre- and post-construction • Use similar site on Block Island for pre- and post-construction surveys

Importance

The proposed avian studies are important to:

- Characterize baseline avian distribution and abundance patterns
- Provide a basis to evaluate potential changes in avian use of the Ocean SAMP study;
- Data to could be used to assess barrier effects and develop collision risk models;
- Better understand current movement ecology by threatened and endangered species and develop models to assess potential impacts on sensitive species;
- Determine avian seasonal and annual use patterns;

- Identify key avian migration corridor, foraging grounds, habitat, and other important use areas; and
- Better understand factors affecting seasonal and annual variability in spatial distribution and abundance patterns.

2.7 Marine mammals and sea turtles (MM&ST)

Characterize spatial distribution, abundance, and seasonality of marine mammal and sea turtle species. The existing data assembled and summarized for the Ocean SAMP project provided relatively good background on the species diversity, abundance, distribution, and seasonality of the marine mammals and sea turtles that occur in Rhode Island and Block Island Sounds. However, there is a lack of detailed, high-resolution information, in both spatial and temporal dimensions, for all species. For some species (smaller sea turtles, seals, and harbor porpoise), even the basic information is weak because those species are difficult to detect during surveys. This goal could be realized through one or a combination methods described in Table 4.

Table 4. Methods for characterizing marine mammal and sea turtle habitat use.

Method	Advantages	Execution
Passive acoustic monitoring arrays	• Provides continuous monitoring for the largest number of marine mammal species • Provides best broad-scale coverage • Can be used for any species that vocalizes	• Arrays could be moorings, fixed bottom mounts, sensors attached to turbine bases, towed arrays • Sensors should be placed within and at decreasing distances from proposed development sites for comparison purposes • Increase sensors = increased coverage area and data richness
Vessel and/or aerial-based surveys	• Provides coverage over large areas over short time periods • Can be used to collect new data or verify passive acoustic monitoring signals	• Surveys should be conducted at least biweekly • Surveys could follow currently ongoing surveys in an area of wind-energy interest south of Martha's Vineyard by a collaborative comprised of URI, New England Aquarium, and the Provincetown Center for Coastal Studies
Tagging studies	• Offers very detailed data of individual marine mammals or sea turtles • Records movement, and therefore, habitat use • Tags may also be equipped to record vocalizations of hosts	• Tags would be tracked remotely (monitored by satellite or by cellular telephone reporting) • Tagging protocols could follow those of NMFS for their programs in Massachusetts and Maine • Studies should begin at least one year prior to construction and continue throughout operation

Importance

Projects focused on marine mammals and sea turtles will be a necessary part of any marine spatial planning activities within U.S. jurisdiction because of the special protections afforded those species under federal legislation (Endangered Species Act, Marine Mammal Protection Act). The proposed marine mammal and sea turtle surveys are valuable to:

- Adequately understand marine mammal and sea turtle distribution and abundance patterns;
- Identify important use areas (seasonal, migratory pathways); and
- Provide a baseline to be used to detect and measure change.

It should be noted that the proposed research would not provide much data to address climate-change effects, since all of the marine mammals and sea turtles in the Ocean SAMP area represent only relatively small subsets of populations with ranges that encompass much larger regions—in some cases most of the North Atlantic Ocean.

2.8 Fish

Identify seasonal habitat use by important fish and invertebrate species. A core challenge of developing spatial management plans is the acquisition of knowledge concerning the distributions, population structure, interactions and trends of key species and communities. To address this challenge, the RI Ocean SAMP sponsored a spatially explicit baseline survey of the demersal fish and invertebrate community in Rhode Island's nearshore waters (Malek et al. 2010). This survey was conducted primarily in the fall season to achieve synoptic sampling of the entire SAMP area. However, many fish and invertebrate species have seasonal migrations and therefore their distributions within the SAMP area differ throughout the year. A monthly otter trawl survey would capture distributional trends of the fish community throughout the year and provide a baseline against which to assess potential impacts of offshore developments. Furthermore, understanding spatial and seasonal patterns in the demersal fish community would allow for turbine construction to be scheduled when effects on vulnerable fish species are minimal. The continuation of a monthly otter trawl survey would provide a unique opportunity to monitor fisheries ecosystem change throughout all phases of wind farm development, from construction to operation to decommissioning. Research goals would be accomplished by sampling a set of 6-8 fixed stations and 4-6 randomly selected stations within the Ocean SAMP area. Randomly selected stations would be stratified by depth and development interest to provide statistical power in future analyses. Sampling would be conducted monthly using a Rhode Island commercial fishing vessel equipped with a ¾ scale NEAMAP-style net and a one inch knotless cod-end liner. Aggregate weights, counts, and individual length measurements would be recorded from all species collected, including lobster and other macroscopic invertebrates. Weather and sea conditions (i.e. wind speed, wind direction, and tidal stage) as well as water column profiles (water temperature, dissolved oxygen, and salinity) would be recorded prior to each tow to investigate the relationship between oceanographic conditions and the demersal fish community.

Sample hard-bottom habitats. The difficulty of towing gear on rough bottoms has resulted in limited sampling of hard-bottom habitats within the Ocean SAMP area and throughout the northeast region of the United States. Several important fish species (scup, sea bass, and tautog) and lobster are associated with hard-bottom environments, but their distribution and abundance are difficult to assess, as they are inadequately sampled. The proposed sampling approaches would be seasonal beam-trawl surveys, ventless traps, and fish pot surveys based on techniques established by the International Council for the Exploration of the Sea (ICES) Study Group on the Development of Fish Pots for Commercial Fisheries and Survey Purposes (SGPOT). The sampling strategy would consider factors like water depth, habitat type, and oceanographic conditions. In addition, a dedicated 7-10 day ROV cruise of moraines and other hard-bottom areas should be performed to further define these complex, high diversity habitats and to complement fisheries data.

Sample pelagic fish species. Pelagic fish are not well sampled despite that many species (herring, shad, menhaden, bluefish, striped bass) are both ecologically and economically important. To understand the distribution and movements of these species, sampling would be done through tagging and/or acoustic studies (Jolly and Hampton, 1990).

Identify fish food-web dynamics. During bottom trawl surveys, stomach samples and tissue samples would be taken from all target species and analyzed for diet composition and nitrogen stable-isotope signatures. These data would be used to discern food-web dynamics, including predator-prey relationships and feeding history (Garrison & Link 2000; Hyslop 1980; Fry 1988; Hansson et al. 1997).

Determine fish-habitat relationships. Efforts to discern relationships between fish habitat and fish geospatial distribution and abundance patterns should continue. This research involves the mapping and sampling of benthic habitats and conducting fish trawl surveys. These data are then examined for statistically significant correlations to identify meaningful relationships of fish-habitat use patterns. Target species or entire fish assemblages may be evaluated.

Importance

The proposed standardized, long-term fish surveys and sampling programs would be useful to:

- Gain a more comprehensive understanding fish spatial and temporal distribution, abundance, and habitat use patterns within the Ocean SAMP area;
- Provide a baseline against which to detect and evaluate impacts, including from offshore development and climate change;
- Identify diverse and sensitive fish habitats that warrant protection;
- Establish seasonal fish abundance and habitat use to ensure appropriate timing of construction activities during the year;
- Investigate biogeographic patterns in predator-prey relationships through diet analysis;
- Quantify the trophic level of predatory species and further define time-integrated feeding history of each consumer using Nitrogen stable isotope analyses. This combination of techniques provides a spatially explicit model of species interactions;

- Establish multidisciplinary links, such as those between fishing patterns, fish distribution/abundance, and benthic habitats, and between seabird foraging, forage fish, and benthic habitats; and
- Establish protocols for effectively sampling hard-bottom habitats. There is a lack of fisheries studies sampling hard bottom, particularly in the northeast region of the United States. There are numerous factors that go into sampling hard bottom, including pot design, bait type, string size, pot spacing, soak time, species specific catchability. This data gap presents a unique opportunity to work with fishermen in Point Judith to develop and test gear and methods for this type of work.

2.9 Fisheries (Commercial and Recreational)

Characterize fishing activity Commercial and recreational fishing are some of the most economically and culturally significant human activities taking place within the Ocean SAMP area. Yet, there lacks adequate understanding of these activities with regard to when and where fishing occurs, species targeted, types of gear used, and economic data (e.g. commercial landings, fishing gear expenses, charter boat revenues). The Ocean SAMP fisheries chapter utilized existing data, including Vessel Trip Report (VTR) data and publically available landings data; while these data showed that commercial and recreational fishing are important within Rhode Island and Block Island Sounds and to the state of Rhode Island, the data presented are insufficient to understand changes to fishing activity as a result of factors such as ORE development and climate change. Therefore, additional information is required to improve understanding of fishing activity. Some of this information may be provided through existing data, such as gaining access and the ability to present data from Vessel Monitoring Systems (VMS) and log books from lobster vessels. However, not all fishing vessels are required to carry VMS, so there is still a need to ensure adequate representation across gear and vessel types. New quantitative and qualitative data describing fishing activity should be collected as well to supplement existing data sources. Such new baseline information could be collected through surveys and mapping exercises with fishermen. Furthermore, observational vessel-based surveys could be conducted, which could take place in conjunction with other research surveys (e.g. avian, marine mammal and sea turtle, fisheries, mapping).

Importance

The proposed study would rectify the fisheries data gap by allowing researchers and management agencies to:

- Better understand the economic and cultural significance of commercial and recreational fishing within the Ocean SAMP area;
- Produce a more comprehensive understanding of fishing activity by examining spatial and temporal scales over which fishing occurs, as well as species targeted, types of gear used, and economic data;
- Establish a baseline of fishing activity to detect changes resulting from renewable energy or other projects, climate change, and/or changes to federal/state regulatory regimes. These results could then be tied to economic data on fisheries landings to evaluate the extent to which any economic effects felt by the fishermen could be contributed to different impacts;
- Identify areas heavily used by fishermen; and

- Establish links between fisheries, fish abundance and distribution patterns, and habitat to provide a more complete understanding of the Ocean SAMP area.

2.10 Cultural and Historic Resources

Assess historic properties. The inventory and the identification of National Register-listed and -eligible historic properties is the critically important initial step in the Section 106 review process for federally funded, permitted, or reviewed undertakings, including ORE projects. Section 106 of the National Historic Preservation Act ("NHPA") of 1966, as amended (36 CFR 800) requires federal agencies take into account the effects of their undertakings on cultural resources listed or eligible for listing in the NRHP (36 CFR 60). The agency must also afford the Advisory Council on Historic Preservation ("ACHP") the opportunity to comment on the undertaking. The Section 106 process is coordinated at the state level by the State Historic Preservation Offices ("SHPOs"), which in RI operates within the offices of the RI Historic Preservation and Heritage Commission ("RIHPHC"). The issuance of federal and CRMC permits for offshore projects within the SAMP will depend, in part, on obtaining comments from the RIHPHC, as well as the comments of local tribal authorities (e.g., the federally-recognized Narragansett Indian Tribe's Tribal Historic Preservation Office) and other interested parties (e.g., local historical societies and concerned citizens). The Ocean SAMP provided a broad contextual framework characterizing the cultural and historic resources within Rhode Island and Block Island Sounds, particularly for identifying potential shipwreck locations (Figure 6; Ocean SAMP Chapter 4). What is now needed is an assessment of historic properties. This process involves a detailed examination and comprehensive inventory of cultural and National Register of Historic Places ("NRHP")-listed and -eligible historic properties located both underwater and onshore in the coastal margin. Within the Ocean SAMP, cultural and historic resources primarily refer to shipwrecks and ancient Native American settlement sites and use areas. The proposed method to identify resources is vessel-based geophysical (side-scan sonar, multibeam echo-sounder, sub-bottom profiler) and imagery (underwater video and photography) surveys. The data is then reviewed visually for indications of resources. Once, found, a resource needs to be identified and documented. In addition, determinations need to be made about excavation and protection. Currently, there is over 100 sq mi of geophysical data from the Ocean SAMP project that could be analyzed for archeological resources.

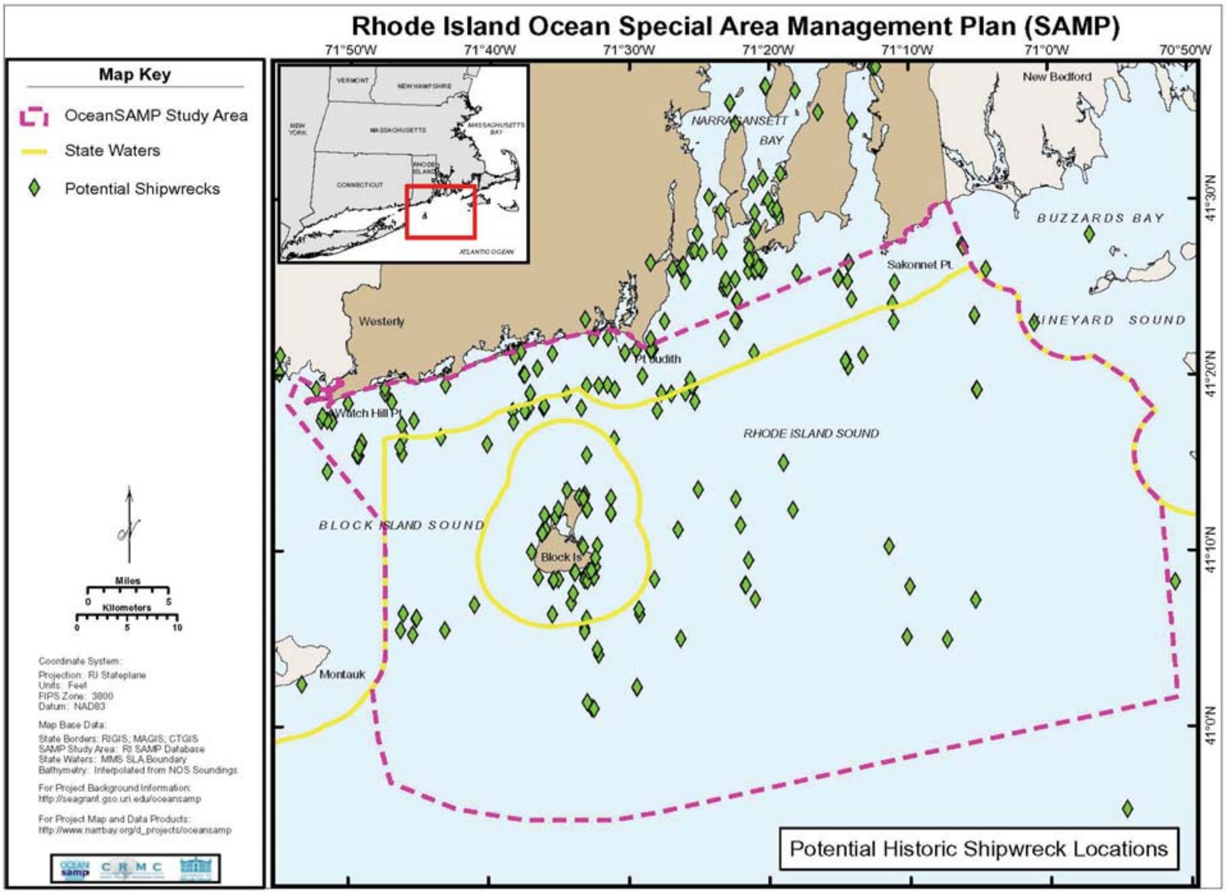

Figure 6. Potential historic shipwreck locations. (From Ocean SAMP Chapter 4).

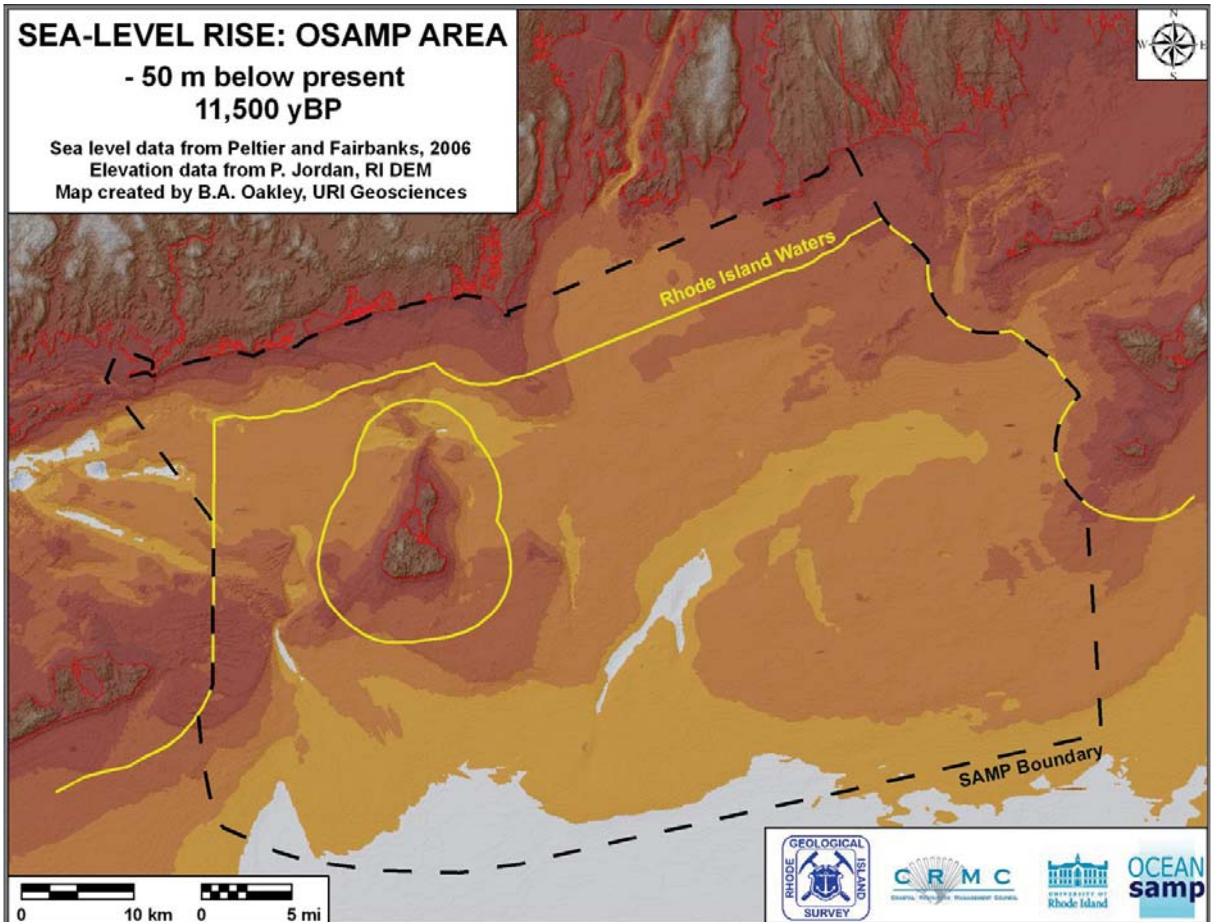

Figure 7. Sea level -50 m. Relative sea level was about 50 meters below present at 11,500 years before present (yBP). Brown colors represent dry land, blue represents water. Marine water is just impinging on the southern Ocean SAMP boundary. Other blue areas are possible lakes in closed depressions. The present-day shoreline is shown by the red lines. (From Ocean SAMP Chapter 4).

Identify submerged paleolandscapes with archaeological sensitivity for containing ancient Native American settlements. Limited work has been performed to reconstruct paleolandscapes within Rhode Island and Block Island Sounds. At 11,500 years before present (yBP), relative sea level was 50 m lower, resulting in the shoreline being located at the southern Ocean SAMP boundary (Figure 7; from Ocean SAMP Chapter 4). It is this time period that the (currently) earliest evidence of human habitation of the northeast appears in the archeological record. From an anthropological perspective, understanding such paleolandscapes is valuable for making better predictions of where submerged landscapes may be, better understanding past human responses to changing environmental conditions, and helping to preserve the cultural history of Native Americans and their ancestors. From a scientific perspective, studies of past climatic and paleoenvironmental conditions may provide a more refined determination of sea-level rise. The proposed study involves geophysical surveying and collecting and analyzing core samples containing formally terrestrial strata.

Importance

The proposed cultural and historical resources research would be valuable to:

- Construct a comprehensive inventory of submerged and coastal historic properties (archeological sites, built resources, and traditional cultural properties) and cultural resources;
- Establish the necessary baseline data for assessing what impacts may result from development and other human activities;
- Better understand paleoenvironmental conditions within the Ocean SAMP dating back to the time of the last ice age;
- Better understand past climatic conditions within the Ocean SAMP, enabling researchers to discern long-term climatic trends from shorter term changes associated with human impacts;
- More precisely calculate the local rate of relative sea-level rise within the Ocean SAMP;
- Better understand past human responses to dramatic climatic changes and sea level rise through the identification and analysis of archaeological deposits of inundated ancient Native American settlements; and
- Increased knowledge about the archaeological resources within the Ocean SAMP may accelerate and simplify development project permitting processes.

As previous Ocean SAMP studies have indicated, cultural and historical resources "also contain ecological as well as cultural and historical information, and many are integrated into marine ecosystems as structures or as parts of the ocean floor environment" (Ocean SAMP Chapter 4). Underwater archaeological research in the marine environment is by its very nature multidisciplinary and collaborative, as much of the same data are collected for benthic habitat characterization (side-scan sonar, multibeam, sub-bottom profiler, underwater video, etc.), physical oceanography studies (water and sediment chemistry, temperature, current directions and velocities, etc.) and fisheries studies (correlations between fishing grounds, fishing methods, and the types, densities, and distributions of shipwrecks, impacts on shipwrecks from different types of fishing, etc.). These links are directly and indirectly applicable to submerged cultural resources identification, assessment and management.

2.10 Recreation and tourism

Characterize offshore recreational activities and tourism. While it is acknowledged that the Ocean SAMP area is culturally significant for recreation and tourism (e.g. boating, sailing, wildlife viewing), there is limited understanding of the distribution of recreational activities. Questions, such as, "When and where are different types of activities occurring?" "How many boats are participating?" "What are size and types of these boats?" "Is the area being used primarily by Rhode Island residents our outside visitors?" need to be addressed to adequately understand the importance of recreation and tourism. Methods proposed to collect this data are public questionnaires and vessel-/aerial-based surveys conducted once monthly, which may occur in combination with other research surveys (e.g. avian, marine mammals and sea turtles, fisheries). Multi-year data would be necessary to account for annual variation (due to weather conditions, economic climate).

Quantify economic value of offshore recreational activities and tourism. The economic impact recreational and tourism activities in the Ocean SAMP area have on the state of Rhode Island is not well understood and the best available data are 10-20 years old (Tyrrell and Johnston 2001; Thunberg 2008). As examples, the only available data for Block Island Race Week dates back to 1986, and a state-wide study done by Ninigret Partners in 2006 found that the 43,000 boats registered in Rhode Island at that time generated approximately $182 million worth of spending each year (R.I. Economic Monitoring Collaborative 2008). However, this figure excludes transients, megayachts (very large yachts), and regatta participants and therefore likely underestimates the economic impact of this industry. To improve our knowledge, the economic value of events (America's Cup, Block Island Race Week) and activities (recreational boating, sailing, wildlife viewing) need to be documented. The upcoming America's Cup events in the summer of 2012 presents such an opportunity.

Importance

The proposed recreation and tourism studies are needed to:

- Identify temporal and spatial contexts at which recreation and tourism occurs;
- Identify types of activities that go on at what intensity;
- Provide a baseline of recreation and tourism activity against which to measure change within the Ocean SAMP area; and
- Examine and quantify the potential impacts on recreation and tourism from offshore development. Specifically, quantifying how activities contribute to the local economies of our coastal communities would provide regulators with a better understanding of the potential consequences of development and demonstrate the importance of considering these uses in management decisions.

The proposed research would benefit from a 5-10 year study period if offshore development occurs, since recreation and tourism activities would probably differ immediately following construction (interest may be generated towards viewing the turbines) versus over time (as turbines become established and excitement decreases).

2.11 Baseline research needs prioritized by location

It is recognized that research priorities may vary based on location. The focus of some of the proposed research projects is to attain a more complete understanding the entire Ocean SAMP study area, whereas other research is specific to areas that may undergo ORE development. Table 5 summarizes what the research priorities are within three areas: (1) the entire Ocean SAMP study area; (2) the Renewable Energy Zone (REZ); and (3) the Area of Mutual Interest (AMI). A description of the boundaries of each of these areas is provided in the Ocean SAMP document. These areas were chosen because they are likely to be the focus of any future funding opportunities.

Table 5. Research needs prioritized by location.

"1" = first priority, "2" = second priority, and blank = complete or not necessary. *Note the research goals identified in section 2 are primary overall needs, whereas this table is more spatially refined, prioritizing research goals based on study location.

	Research needs	Study Area		
		BI	AMI	Ocean SAMP
Observation stations	Establish a series of fixed buoy monitoring stations for multidisciplinary data acquisition	1	1	1
Habitat	Mapping of priority areas		1	
	Continue to improve habitat template and ecosystem services typology models	2	2	1
	Validate and refine models	2	2	1
	Develop indicators of seafloor disturbance	2	2	1
Ecology	Measure ecological parameters	2	2	1
	Develop models	2	2	1
	Measure benthic community organic matter consumption and nutrient regeneration	2	2	1
Fish	Identify seasonal habitat use	1	1	1
	Sample hard-bottom habitats	1	1	1
	Sample pelagic fish species	2	2	1
	Identify fish food-web dynamics	2	2	1
	Determine fish-habitat relationships	2	2	1
MM&ST	Characterize spatial distribution, abundance, and seasonality			1
Avian	Assess baseline distribution and abundance	1	1	1
	Examine movement ecology of birds	1	1	1
	Investigate factors affecting variability in avian distribution and abundance patterns	1	1	1
Physical oceanography	Measure physical oceanographic parameters	2	2	1
	Develop models	2	2	1
Fisheries (commercial, recreational)	Characterize fishing activity	2	2	1
Cultural and historical resources	Assess historic properties	1	1	2
	Identify submerged paleolandscapes with archeological sensitivity for containing ancient Native American settlements	1	1	2
Recreation and tourism	Characterize recreational activities and tourism	1	1	2
	Quantify economic value of offshore recreational activities and tourism	1	1	2

3.0 Research Focused on Impact Assessment

3.1 Measuring Impacts of Offshore Renewable Energy (ORE) Development

The recent interest in ORE within the United States has initiated concerns of impacts to the environment and on human activities. The development of suitable research programs and protocols to monitor and measure effects of ORE is of national importance. Impact assessment of ORE involves the identification and evaluation of the range and magnitude of potential effects associated with development (construction, operation, and decommissioning) on natural resources and human activities. Assessments are a vital step for any ORE project, providing evidence of impact occurrence, intensity, and sources. This information is critical for implementing appropriate management and mitigation strategies.

Impacts are identified through monitoring activities, which may be structured as a continuation of ongoing baseline studies. While baselines are important for understanding the current state and natural fluxes of an ecosystem, monitoring is useful for identifying deviations from that state. Deviations could be a result of ORE development or other disturbance events (e.g. fishing, storms) or climate change. Similarly, just as long and detailed baselines are necessary to sufficiently understand biological and environmental patterns and processes, long-term monitoring is required to adequately characterize changes and their causation. In addition, having an extended multidisciplinary data series enables understanding of the ecosystem over suitable spatial and temporal scales, further facilitates investigations of relationships and trends between data, and promotes the development of models and change scenario applications.

Modeling and change scenarios

Models and change scenarios are important tools for adaptive management and prior to any decision-making, as model results can be used to weigh different development scenarios against one another. Specifically, models provide insight into how changes to the environment (e.g. development, increasing temperature, increasing wind) may influence different aspects of the ecosystem and the ecosystem as a whole, build an understanding of the system (attributes, patterns, and processes), promote multidisciplinary investigations of relationships within the system, and may provide explanations for observed or predicted alterations to the system.

It is important to note that accurate impact assessment and modeling relies on sufficient baseline data, which reiterates the importance of Section 2.0. While an extensive database was compiled from existing and new data collected during the Ocean SAMP, additional data (discussed in Section 2.0) will allow for higher spatial and temporal physical and biological baseline conditions to be established for the Ocean SAMP area.

Impact assessment study duration and location

As with baseline data, the proposed monitoring programs and demonstration projects should occur throughout the Ocean SAMP region within and outside of areas proposed for wind turbine and other offshore development. Having undeveloped "control" sites permits comparisons to be made with developed sites and facilitates better understanding of development impacts. With regard to duration, monitoring efforts should be sustained over a period of years to capture variability and sufficiently understand it. Demonstration projects should occur long enough to understand initial, short-term, and long-term impacts to the area.

3.1.1 Monitoring Programs

Two monitoring strategies should be implemented within the Ocean SAMP study area. The first is extending the baseline research needs discussed in Section 2.0. Monitoring is a natural extension of baseline studies, and continuing these studies would allow direct comparisons within the data series over time, and may measure changes to the ecosystem due to natural and human-induced events (e.g. climate change, storm activity, wind energy facilities, fishing activity, spills).

The second monitoring strategy is currently being undertaken by the University of Rhode Island (URI) through its participation in the Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship project, as part of the National Oceanographic Partnership Program (NOPP). This project has further placed Rhode Island in the forefront in the United States for identifying and assessing development impacts of ORE facilities on marine resources (environmental, biological) and human activities. The focus of this monitoring project is two-fold. First, the project identifies potential effects of ORE at various development scales (demonstration, commercial, multiple commercial), indicates the anticipated intensity of those effects, and suggests where additional data is needed. Secondly, the monitoring project aims to develop comprehensive protocols for measuring effects of ORE development. To accomplish these tasks, URI has completed an exhaustive literature review of nationally and internationally published work on monitoring methods, and is now in the process of assembling and testing these methods to produce the most effective suite of protocols. The reports generated from this project will provide a national service.

A wind facility consisting of 5-8 turbines is being proposed within the Renewable Energy Zone (REZ) off of Block Island. This proposed demonstration-scale project would present a unique opportunity to directly detect, assess, and monitor impacts on marine resources and human activity in the immediate and surrounding environment of the ORE facility. Specifically the proposed Block Island ORE project would be valuable to:

- Better understand potential development effects of renewable energy on natural resources and human activities within the Ocean SAMP area;
- Design monitoring protocols and establish programs for assessing impacts;
- Guide adaptive management strategies. As an impact is being monitored, mitigation policies can be enacted, or requirements can be instituted to prevent its occurrence in the future;
- Validate and refine models and change scenarios of the Ocean SAMP area developed from baseline data; and
- Promote collaboration with research groups and management agencies to design standardized monitoring protocols and cumulative impact

assessment tools in conjunction with one another to increase their overall compatibility and effectiveness, and reduce research costs and time.

It is recognized a demonstration-scale project may not reveal all effects of larger-scale ORE developments, but it would provide a strong starting point.
The tables in sections 3.1.1 – 3.1.7 describe the NOPP monitoring protocols and provide examples of methods to accomplish them. For these tables "cost" is described as low (<$100,000), moderate ($100,000-$500,000), and high (>$500,000) per year.

3.1.2 Benthic habitat and ecology

Benthic Environment Monitoring Protocol 1: Sediment Scour and/or Deposition. Assess changes in sediment scour and/or deposition around ORE devices.

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; 1 post-construction survey	1 preconstruction survey; Annual operation; 1 post-construction survey
Spatial Scale	200m – 1km radius around 3 devices	500m radius around 3 devices
How well does this methodology account for environmental variability?	Seasonal and interannual variability	Interannual variability
Cost	Moderate	Low
Relationship to Other Protocols:	Can be combined with benthic community composition monitoring protocol (Protocol Z2)	
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., 2001

Benthic Environment Monitoring Protocol 2: Changes in benthic community composition. Assess changes in benthic community composition at or in vicinity of ORE installation.

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) ~0.1m²/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; 1 postconstruction survey	1 preconstruction survey; Annual operation; 1 postconstruction survey
Spatial Scale	200 m radius around 5 devices	200m radius around 3 devices
How well does this methodology account for environmental variability?	Seasonal and interannual variability	Interannual variability
Cost	Moderate	Low
Relationship to Other Protocols:	Can be combined with scour/deposition monitoring protocol (Protocol Z1) Can be combined with reef effects monitoring protocol (Protocol Z3)	
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., 2001	

Benthic Environment Monitoring Protocol 3: Reef Effects. Assess change (e.g. increase) in hard bottom habitat (reef effect) and non-native species at or in vicinity of ORE installation.

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
How well does this methodology account for environmental variability?	Seasonal and interannual variability	Interannual variability
Cost	Moderate	Low
Relationship to Other Protocols:	Can be combined with Fisheries Monitoring Protocol X3	
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 Environment Monitoring Protocol 4: Hydrodynamics. Assess changes in hydrodynamics due to ORE development.

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
How well does this methodology account for environmental variability?	Depending on length of deployment, captures from tidal to interannual variability	
Cost	Moderate	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., 201	

3.1.3 Avian

Avian Protocol 1: Ship Visual Surveys. Assess changes in spatial distribution and abundance of marine birds* due to ORE development. *(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 A).
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 ORED device and predicted environmental effects.
Strengths	• High detection probabilities for most species of marine birds. • Possible to collect other covariates simultaneously including: sea surface temperature, chlorophyll, salinity and bioacoustics data. • Ability to identify individuals to species for targeted taxa (e.g., federally-listed Roseate Terns). • Ability to determine age and/or gender for some species to model population dynamics. • Surveys prior to 2005 were ship-based surveys, so 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.
Limitations	• 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 W1 and Fisheries Resources Protocol X1
Cost	• Moderate (depends on number of surveys)
Type of Data Collected	• 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, wind direction).
Data Output	• Spatially-explicit density estimates (and associated variance) by species within and outside the development area.
Examples where this technique has been used for ORED monitoring	• 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 2: Aerial Visual Surveys. Assess changes in spatial distribution and abundance of marine birds* due to ORE development. *(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 A) 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.
Strengths	• High detection probabilities for most species of marine birds. • Able to detect disturbance-prone species. • Able to potentially simultaneously survey marine mammals.
Limitations	• 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. • Found to 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 W1, and Fisheries Resources Protocol X1
Cost	• Moderate (depends on number of surveys)
Type of Data Collected	• 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, wind direction).
Data Output	• Spatially-explicit density estimates (and associated variance) by

	species / taxonomic groups within and outside development area.
Examples where this technique has been used for ORED monitoring	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 3: Aerial Surveys with High Definition Videography. Assess changes in spatial distribution and abundance of marine birds* due to ORE development. *(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 A).
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 than 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.
Strengths	• High detection probabilities for all marine birds • 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. • Permanent record of observations that could be reviewed by biologists in the future. • Spatially-explicit density estimates. • Potential to estimate of flight altitude of individuals or flocks. • Able to survey marine mammals and sea turtles simultaneously.
Limitations	• Not suitable for nocturnal migrants such shorebirds (Charadriiformes) and songbirds (Passeriformes). • Technology is still evolving. • Similar species may not be identifiable depending on imagery.
Relationship to Other Protocols	• Can be conducted in combination with Marine Mammals & Sea Turtles Protocol W1, and Fisheries Resources Protocol X1
Cost	• High (depends on number of surveys)

Type of Data Collected	• Spatially-explicit density estimates of individuals or flocks to within 100 m of actual locations. • 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, wind direction).
Data output	• Spatially-explicit density estimates (and associated variance) by species / taxonomic groups within and outside development area.
Examples where this technique has been used for ORED monitoring	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 4: Aerial Surveys with Digital Still Photography. Assess changes in spatial distribution and abundance of marine birds* due to ORE development. *(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 A).
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 than 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.
Strengths	• 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. • Permanent record of observations that could be reviewed by biologists in the future. • Spatially-explicit density estimates • Potentially estimate of flight altitude of individuals or flocks. • Able to survey marine mammals and sea turtles simultaneously.
Limitations	• 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 W1, and Fisheries Resources Protocol X1
Cost	• High (depends on number of surveys)

Type of Data Collected	• Spatially-explicit density estimates of individuals or flocks to within 100 m of actual locations. • 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, wind direction).
Data output	• Spatially-explicit density estimates (and associated variance) by species / taxonomic groups within and outside development area.
Examples where this technique has been used for ORED monitoring	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 5: Radar Surveys. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

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 and 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	• 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.
Strengths	• Flight trajectories can be stored in GIS. • Provides quantitative data on diurnal and nocturnal movements • 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 flight altitude information. Can be combined with ground truthing to make detections species specific.
Limitations	• Generally cannot identify targets to species. • 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 often make data unusable. • X-band radar more susceptible to rain clutter. • Can be challenging to develop precise quantitative counts due to issues with detection probabilities.
Cost	• High (due to need for stable platform)
Type of Data Collected	• Number of targets per hr 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 technique has been used for ORED monitoring	Krijgsveld et al. 2010; Desholm et al. 2004.

Avian Protocol 6: Visual Surveys of Flight Ecology. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

Indicator(s) of Impact	Changes in flight paths of foraging or commuting birds within development area.
Methodology or Technique to Collect Data	Visual Surveys (Ground-truthing radar surveys).
Description of Methodology or Technique(s) for Collecting Data	• Visual observations to identify species detected by radar. • 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.
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	• Depends on if X- or S-band radar is used, but generally within 1-3 km of radar unit.
Strengths	• 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.
Limitations	• 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	• Low for observers in coastal sites
Type of Data Collected	• Speciation of flocks or individuals recorded on radar.
Data Output	• Flight intensities (i.e., targets per hour) and flight altitude of target species.
Examples where this technique has been used for ORED monitoring	• Krijgsveld et al. 2010

Avian Protocol 7: Flight Call Surveys. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

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 (Ground truth radar 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. • Observations conducted from a stable platform near radar unit where individuals or flocks can be heard prior to entering buffer surrounding wind farm. • Communication between observer and radar operator.
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	• Development area.
Strengths	• Only way to identify radar targets to species at night. • Primarily useful for passerines.
Limitations	• Limited detection probability for calling targets. Some species do not call when flying at night. • Working on offshore platforms can be dangerous.
Cost	• Moderate (due to working on offshore platform)
Type of Data Collected	• Identification of radar targets to species.
Data Output	• Relative flight call intensities (i.e., calls per hour by species).
Examples where this technique has been used for ORED monitoring	Krijgsveld et al. 2010

Avian Protocol 8: Radio Tracking. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

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 for Collecting Data	Radio tracking using VHF or nanotags Best for short-range tracking (<25km).
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.
Strengths	• 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.
Limitations	• 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	• Moderate (depends on number of individuals tracked and their locations)
Type of Data Collected	• Real time locations of target species
Data Output	• Phenology of spatially-explicit movements of target species.
Examples where this technique has been used for ORED monitoring	Perrow et al. 2006; Walls et al. 2009.

Avian Protocol 9: Satellite Tracking. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

Indicator(s) of Impact	Changes in flight paths of foraging or commuting 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 lat/longitude. • Observers not required to track birds.
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	• Development area
Strengths	• 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.
Limitations	• More suited for large scale movements; not useful for fine-scale. • Depending on target species, transmitters may have to be surgically implanted; a veterinarian would need to be hired for this procedure. • 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	• Low (Depends on number of individuals tracked)
Type of Data Collected	• 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 technique has been used for ORED monitoring	Griffin et al. 2010; Walls et al. 2009.

Avian Protocol 10: GPS Tracking. Assess changes in avian movement ecology, such as migration and foraging flight paths between foraging and roosting sites due to ORE facility.

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 which 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.
Strengths	• 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.
Limitations	• 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. • Studies have shown that tags should not be more than 3% of body mass. • Trade-off between battery life and data collection.
Cost	• Low (Depends on number of individuals tracked)
Type of Data Collected	• 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 technique has been used for ORED monitoring	Walls et al. 2009.

Avian Protocol 11: Thermal Animal Detection System. Assess direct mortality (above-water collision) of marine birds due to ORE development.

Indicator(s) of Impact	Birds found dead or injured due to direct collision with infrastructure above the water.
Methodology or Technique to Collect Data	Thermal Animal Detection System (TADS)
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.
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.
Strengths	• Ability to remotely monitor collision risk 24 hours per day, 7 days per week. • Can detect nocturnal targets including bats.
Limitations	• Low optical resolution makes identifying to species difficult. • Difficult in harsh offshore conditions. • Uncertainty of effectiveness in inclement weather.
Cost	• Low (depends on how many TADS are put in place)
Type of Data Collected	• 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 technique has been used for ORED monitoring	Walls et al. 2009; Desholm et al. 2004; Desholm et al.. 2006.

Avian Protocol 12: Sonar and Video Technology. Assess direct mortality (under water-collision) of marine birds due to ORE development.

Indicator(s) of Impact	Birds found dead or injured due to direct collision with infrastructure under water.
Methodology or Technique to Collect Data	Point count could be used to Monitor avian use of project area from surface using a point count. 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 period when diving birds could be in study area. • One year post-construction.
Spatial Scale	• Project area.
Strengths	• Allow quick determination if potentially vulnerable species (diving birds) are using the study area. • Cost effective compared to other potential strategies
Limitations	• 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	• Moderate
Relationship to Other Protocols	• Can be conducted in combination with Fisheries Resources Protocol X4
Type of Data Collected	• Number of individuals of target species detected in study area.
Data Output	• Number of vulnerable targets (diving birds) in study area.
Examples where this technique has been used for ORED monitoring	None to our knowledge

3.1.4 Marine mammals and sea turtles (MM&ST)

Methodologies related to MM&ST monitoring in response to ORE development are described in detail below, followed by a series of tables summarizing specific monitoring needs and methodologies. Extensive descriptions exist for these protocols; the reader to referred to the NOPP Task 1.5 report.

Methodology descriptions

Passive acoustic monitoring (PAM) arrays. These sensors can be used to monitor changes in species distribution, abundance, and habitat use patterns, allowing direct relationships between marine mammal movement and noise disturbance to be evaluated. Monitoring can be done using anchored moorings, bottom-mounted hydrophone arrays, towed arrays, or sonobuoys deployed off aircrafts or ships. Most detect only presence/absence within a range of the sensor, which varies with source level and local acoustic propagation conditions. Some sensors can provide bearings to targets; two or more intersecting bearings provide source location. An array of multiple sensors can provide locations from arrival time differences. A large enough array of PAM sensors can provide continuous tracking of vocalizing individuals. Furthermore, PAM is also valuable for assessment of sound levels produced by construction, operation, and decommissioning activities.

Tagging studies. Tags track the movements of individuals and, therefore, could directly address many unknowns about development impacts on marine mammal and sea turtles, including how individuals react to turbines (avoidance, confusion, no reaction) and how distribution and abundance patterns may be altered. There are various tags that can be employed depending on the level of information desired.

Visual surveys. 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. During the 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.

Marine mammal observers (MMO). Marine Mammal Observers are trained observers posted on board vessels in an active construction or operational area. MMOs can be posted aboard construction vessels, service vessels transiting between the work area and shore facilities, or dedicated MMO vessels. The primary objective often is mitigation—detection of animals in potential zones of injury and shutting down operation and/or stopping or diverting vessels.

Harbor seal observers and tagging. The population most likely to be impacted by the initial installation of wind turbines in state waters off Block Island would be the harbor seals that make use of several haul-out sites around the island. To better understand the impacts, it is propose that a year-round shore-based observer be placed on Block Island. The observer would watch over the wind turbine areas from fixed vantage points on the bluffs using calibrated "big eyes" binoculars, and conduct periodic counts of seals at haul-outs around the island during the September-April "seal season." In addition, seals would be tagged to monitor their movements. Animals should be tagged at both at Block Island and at another haul-out site away from the wind turbines for comparison purposes.

Stress hormone assessments. Measurement of levels of stress-related corticosteroid hormones and/or their metabolites is a standard biomedical technique. Quantifying stress hormone levels in animals potentially affected and not affected by noise in a Before-After-Control-Impact (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, but methods have recently been developed for measuring steroid hormones in fecal samples and in breath samples.

Stranding networks. There are regional stranding response networks comprised of multiple cooperating organizations coordinated by the relevant NMFS Regional Office (Anonymous, 2010). 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. 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. Given sufficient standardization of response and data collection, a Before-After-Control-Impact (BACI) analysis of stranding data could be possible.

ROV surveys. Remotely operated vehicles can survey areas directly surrounding structures to be removed. Unlike diver surveys, they are not weather or sea state dependent, but they share the disadvantage of missing turtles due to their obtrusive nature.

Time-lapse underwater photography. 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.

Diver surveys. Use of divers is a relatively low-cost method that involves a diver(s) visually surveying the area around and within the base of a structure to look for resident animals. For diver safety, these surveys are weather/sea state–dependent and tend to underestimate turtles, likely due to observer interference.

Summary tables

MM and/or ST Protocol 1: Visual surveys. *(Can also be applied for pre-siting baseline studies)*

Monitoring objectives:
Construction Noise (pile driving)/Decommissioning Noise (pile removal, explosives): Mortality, injury, or disturbance of MM or ST 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 of populations; Presence of dead or injured animals.
Summary of Methodology or Technique(s) to Collect Data	• 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. • Can secondarily provide data for mitigation, e.g., provide advance warning of animals nearby or approaching impact zone. (See Appendix B 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 MM&ST species within 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 BACI analysis on geospatial data given an appropriate sampling design.
Frequency and Duration	Optimum would be at least 1 year 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 ideally 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.

How well does this methodology account for environmental variability?	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.
Cost	Moderate to High
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).
Relationship to other protocols	Survey data can provide ground-truthing (confirmation of species IDs) for passive-acoustic monitoring (Protocol W2). Surveys can alert MMOs to animal presence (Protocol W3), or pass on observations of dead or injured animals to stranding responders for recovery and necropsy (Protocol W4).
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 which 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

MM Protocol 2: Passive Acoustic Monitoring. *(Can also be applied for pre-siting baseline studies)*

Monitoring objectives:
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 of populations.
Summary of Methodology to Collect Data	Passive acoustic monitoring essentially involves listening to ambient sounds and identifying vocalizations produced by marine mammals.
Methodology for Analyzing data	BACI analysis on a variety of data metrics.
Frequency and Duration	Optimum would be at least 1 year prior to 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 ideally 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.
How well does this methodology account for environmental variability?	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.
Cost	Moderate to High
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.
Relationship to other protocols	Data can feed into other MM&ST protocols.
Data Format	The data output from passive-acoustic monitoring will depend heavily on the sensors and sampling methodology employed
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., 2009a)
Examples where this methodology has been used:	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; Tyack et al., 2011; NMFS, 2010d, 2010e; Risch et al., 2012

MM&ST Protocol 3: Marine Mammal Observers (MMOs).

Monitoring objectives:
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.
Summary 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.
Methodology for Analyzing data	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.
Cost	Low
Other Considerations (E.g. Advantages or Disadvantages)	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 W1 and W2) can alert MMOs to animals near or approaching the impact zone.
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.
Examples where this methodology has been used:	MMS, 2009; NMFS, 2003; NMFS, 2010c; DON, 2009b

MM&ST Protocol 4: Stranding Response Networks.

Monitoring objectives:
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.
Summary of Methodology to Collect Data	Visual survey; Passive acoustic monitoring; MMOs Stranding network; Tagging; Stress hormones
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.
Cost	Low
Other Considerations (E.g. Advantages or Disadvantages)	Stranding networks are already in place and would require only enhancement to be effective for monitoring purposes.
Relationship to other protocols	Data feed into other MM&ST protocols.
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

MM&ST Protocol 5: Tagging.

Monitoring objective: Disturbance of marine mammals or sea turtles by noise, activities, or structures from ORE development.

Indicator(s) of the impact	Detection of changes in fine-scale distribution, movement, or behavior of individuals.
Summary 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.
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.
Cost	Moderate to High
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.
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 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).
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

MM & ST Protocol 6: Stress Hormone Assessment.

Monitoring objective: Quantification of physiological stress related to disturbance from ORE development activities.

Indicator(s) of the impact	Elevated levels of stress-related corticosteroid hormones in animals subject to disturbance from activities associated with ORED development.
Summary 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 would 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.
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.
Cost	Moderate
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.
Data Output:	Stress hormone concentrations from samples collected in control and impact areas or from along an exposure gradient.
Examples where method-ology has been used:	Rolland et al. 2007; Hogg et al. 2009; Rolland et al. 2012

MM&ST Protocol 7: Underwater Photography.

Monitoring objective: Disturbance or loss of habitat of sea turtles by device removal during decommissioning of ORE devices.

Indicator(s) of the impact	Disturbance of animals during cable or device removal; detection of dead or injured animals
Summary of Methodology 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
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/SCUBA survey efforts
Spatial Scale	Small: Area immediately surrounding structure to be removed
Cost	Low
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 3
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 method-ology has been used:	Rosman et al., 1987; Klima et al., 1988

MM&ST Protocol 8: SCUBA Surveys

Monitoring objective: Disturbance of sea turtles during cable installation or removal; Disturbance or loss of habitat of sea turtles by ORE 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
Summary of Methodology to Collect Data	SCUBA diver surveys (e.g. during cable laying/removal or around structures to be decommissioned/removed)
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/SCUBA survey efforts
Spatial Scale	Small: Area immediately surrounding structure to be removed
Cost	Low
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 7 and 9; Fisheries Protocol 3
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 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

MM&ST Protocol 9: ROV Surveys

Monitoring objective: Disturbance of sea turtles during cable installation or removal; Disturbance or loss of habitat of sea turtles by ORE 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
Summary 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
Cost	Low if combined with fisheries surveys; moderate if conducted independently
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 W7 and W8; Fisheries Protocol W3
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

3.1.5 Fish

Fisheries Protocol 1a- Trawl Surveys. Monitor for changes in meso-scale distribution and abundance of fish species in the vicinity of an ORE 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 catchability (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 no less than 1km 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 3 knots • Trawl duration 20 minutes
Methodology for Analyzing data	ANOVA on numbers of individuals, size and weight distribution; multivariate analysis of catch/community composition, multidimensional scaling, cluster analysis (Primer-E)
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
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
How well does this methodology account for environmental variability?	Seasonal and interannual variability
Cost	Moderate (depends on number of surveys)
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.
Relationship to Other Protocols:	Can be combined with Fisheries Protocol X1b or X2
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 1b - Ventless Trap Surveys. Monitor for changes in distribution and abundance of lobster/crab species or some fish species in the vicinity of an ORE installation.

Indicator(s) of the impact	• Shift in distribution (of lobster, crab, rock fish) or abundance overall or on a seasonal basis • Shift in species composition • Increase or decrease in catchability (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
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)
How well does this methodology account for environmental variability?	Seasonal and interannual variability
Cost	Low
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.
Relationship to Other Protocols:	Can be combined with Fisheries Protocol X1a or X2
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, B., and K.D.E. Stokesbury. 2011.

Fisheries Protocol 2- Monitoring for project-scale changes.

Monitoring objectives:

- Monitor for micro-scale changes in abundance or species composition of fish around ORE structures or along cable routes, including non-native species, resulting from disturbance (from noise, presence of devices), or attraction to ORE devices (aggregation or reef effects).
- Monitor for changes in catchability of commercially and recreationally targeted fish in the vicinity of the ORE installation.

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 catchability (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	<u>Gillnet or trammel net surveys:</u> • 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 <u>Beam trawl surveys:</u> • 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
How well does this methodology account for environmental variability?	Seasonal and interannual variability
Cost	Low

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)
Relationship to Other Protocols:	Can be combined with Fisheries Protocol X1a or X1b
Data Format:	<u>Gillnet/trammel net:</u> Catch per unit effort (CPUE) # Individuals per species and area Diversity Length frequency distribution of dominant and/or vulnerable species <u>Beam trawl:</u> 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 3a and 3b- Reef and Aggregation Effects. Monitor for changes in abundance or species composition of fish around ORE structures, including non-native species.

	3a: Depth of installation < 20 m	3b: 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 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. • 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 • Transects of 15-30 min duration • Estimation of species length
Methodology for Analyzing data	ANOVA on # species, # of fish, multivariate analysis of fish community characteristics (Primer-E), multidimensional scaling, cluster analysis	ANOVA on # species, # of fish, multivariate analysis of fish community characteristics (Primer-E), multidimensional scaling, cluster analysis
Frequency and Duration	• 4 seasonal baseline surveys during pre-construction • seasonal surveys 4x/yr for 5 yrs minimum during operation	• 2 baseline surveys during pre-construction (spring and fall) • seasonal surveys 2x/yr for 5 yrs minimum during operation
Spatial Scale	Small to medium	Small
How well does this methodology account for environmental variability?	Seasonal and interannual variability	Seasonal and interannual variability
Cost	Low (depends number of surveys)	Low
Other Considerations (E.g. Advantages or Disadvantages)	Can be combined with reef effect protocol for benthic habitat	Can be combined with reef effect protocol for benthic habitat
Relationship to Other Protocols:	Can be combined with Fisheries Protocol 2 or Marine Mammal and Sea Turtle Protocols 6-8 or Benthic Environment Monitoring Protocol 2	
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, K.R. and J.H. Render. 2003; Love, M, J. Hyland, A. Ebeling, T. Herrlinger, A. Brooks, and E. Imamura. 1994.	Wilhelmsson, D., T. Malm, and M. Ohman. 2006.

Fisheries Protocol 4: Blade Strikes. Monitor for blade strikes from tidal energy devices.

Indicator(s) of the impact	Observation of blade strike incidents
Methodology 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
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
How well does this methodology account for environmental variability?	Some seasonal variability
Cost	Moderate
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 12 or Fisheries Protocol 2
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 method-ology has been used:	Verdant Power 2010.

Fisheries Protocol 5 – Spatial Use of Fishing Activity. Monitor for changes in the spatial distribution of fishing activity (commercial and recreational) around ORE installation.

Protocol	5a	5b
Indicator(s) of the impact	• Changes in numbers of vessels fishing near or inside of the ORE area (more or fewer vessels) • Change in the presence of fixed fishing gear (gillnets, pots, traps) inside of or around ORE 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 5 years post-construction	• Year-round survey of fixed fishing gear and vessel activity • 2 years pre-construction, during construction, and 5 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
How well does this methodology account for environmental variability?	Accounts for seasonal variability, and somewhat for interannual variability	Accounts for seasonal variability, and somewhat for interannual variability
Cost	Moderate (depends on the number of VMS units required)	Low

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 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.	- This methodology will be less expensive than installing VMS systems (depending on the number of vessels/VMS systems to be installed). - 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.
Relationship to Other Protocols:	Can also be combined with Avian Species Monitoring Protocol 1 and Marine Mammal and Sea Turtles Monitoring Protocol 1	
Data Format:	Vessels/area Distribution of vessel types	
Data Output:	Spatial Use Maps	
Examples where methodology has been used:	Wiley, D.N.; Moller, J.C.; Zilinskas, K.A.. 2003.	

3.1.6 Fisheries

The for-hire fishing industry is a significant recreational activity and economic driver within the state of Rhode Island. In 2009, there were 240 active party and charter boat licenses issued by the Rhode Island Department of Environmental Management. The waters off Block Island are heavily used by this industry because of the variety of different species found here throughout the year that are attractive to anglers.

The construction of five wind turbines off the coast of Block Island may have a variety of effects on both targeted fish species and on fishing activity, and may pose a threat to the viability of the party and charter boat industry. During construction, party and charter vessels will be displaced from the vicinity of construction activity. Construction noise along with vessel activity may cause fish to leave the area, decreasing catchability. Furthermore, little data exists to suggest what changes to fish distribution and abundance may occur once turbines have been constructed and are operational. Some of the species targeted by the party and charter boat industry may move elsewhere in response to habitat disturbance, whereas other evidence suggests the placement of new structures in the marine environment will result in reef effects as benthic organisms growing on the turbine foundations attract various species seeking food or shelter. In the Gulf of Mexico, reef effects have created habitat for numerous recreationally-targeted fish species on the jacketed structures of oil rigs, and in return these oil rigs serve as important fishing grounds for recreational fisheries. The jacketed structures of the wind turbines planned for construction off Block Island may have similar reef effects. However, fish species most commonly targeted by the party and charter boat fleet are pelagic species, including striped bass and bluefish, which may not be attracted to new structures in the water.

The above-mentioned potential effects to party and charter boats could also have secondary economic effects. For example, if during the construction period, vessels are forced to travel further, or to areas where fish are less abundant, this could have negative economic consequences for their businesses. Likewise, if the most desirable species become more difficult to catch on a short-term or long-term basis, a loss of clients paying for fishing trips could result. Conversely, if reef effects concentrate or attract fish, and increase catchability, wind turbines could eventually be seen as a boon to the industry.

In partnership with the Rhode Island party and charter boat industry, we propose to determine the changes in activity and catch level of the party and charter boat industry during pre-construction, construction, and post-construction periods within and surrounding the Ocean SAMP REZ (Figure 2). This data will allow researchers to: 1) develop a baseline for where fishing is taking place; 2) determine effects of construction on spatial use of the area by the party and charter boat industry; and 3) document activity changes within waters around Block Island post–construction.

We also propose to analyze economic effects of the potential changes to fishing activity as a result of the construction and operation of the Block Island wind farm by documenting changes in: 1) the number of paying clients during this time period; 2) the number of return clients; and 3) the changes to the cost of fishing during this time.

Fisheries protocols 1, 2, and 5 (section 3.1.5) directly address these concerns.

3.1.7 Recreation and Tourism

Changes in perceptions of tourists and recreational boating activity during the three phases of ORE development off Block Island. The proposed study aims to measure changes in recreational boating activity as a result of the installation of the offshore wind turbines, and also gauge the perceptions of tourists to the island. Block Island is an important driver for tourism in the state of Rhode Island, attracting over half a million visitors per year (Global Insight, 2008), including recreational boaters. The construction of five wind turbines off Block Island's shore adds an unknown element to the island's tourism industry. The novelty of turbines may attract tourists or recreational boaters who wish to view them; on the other hand, the new turbines may negatively influence perceptions of tourists attracted to the island's relatively unspoiled views. Moreover, during construction recreational boaters will likely be excluded from the project site for safety reasons. The Ocean SAMP recognized this potential effect, particularly around Block Island; Section 1160.9, Monitoring Requirements #2 stated:

> "The Council shall require where appropriate that project developers perform systematic observations of recreational boating intensity at the project area at least three times: pre-construction, during construction, and post-construction. Observations may be made while conducting other field work or aerial surveys and may include either visual surveys or analysis of aerial photography or video photography. The Council shall require where appropriate that observations capture both weekdays and weekends and reflect high-activity period including the July 4th holiday weekend and the week in June when Block Island Race Week takes place. The quantitative results of such observation, including raw boat counts and average number of vessels per day, will be provided to the Council."

With regard to the perceptions of tourists visiting the island, qualitative surveys will be used. Tourists will be asked to evaluate what they view as the positive and negative impacts of the construction and operation of the Block Island wind farm, including what they believe are potential environmental effects. Surveys will be conducted and responses analyzed both before and during construction, as well as once the facility is operational to determine how perceptions change during the different phases of the project.

Changes in recreational boating will be quantified through weekly visual surveys recording boat counts and types of activity occuring at the project site and two other sites (controls) around the island during summer months (May – September). These surveys should be conducted at least one year before construction begins, during the construction of the facility, and for multiple years once the project is operational. Surveys will be conducted using a methodology developed at the University of Rhode Island by Thompson and Dalton (2010). Data will be analyzed to assess changes in the number of boats utilizing the project site and the control sites. Geospatial analysis will also be conducted to evaluated whether boating activity is being shifted to other areas around Block Island. Because the project may potentially span up to 5 years, this study will be able to measure both immediate changes caused by construction activities and longer-term impacts to recreational boaters at/near the project site. Changes in intensity and types recreational boating activities will also be evaluated and analyzed to determine the economic impact such of changes.

3.2 Measuring the Impact of Climate Change

Marked climate change impacts have been/are being seen in shallower systems adjacent to the Ocean SAMP area (Narragansett Bay and Buzzards Bay). Over the last century, air and sea temperatures, precipitation, sea level and cloudiness have increased in New England (Smith et al 2010; Nixon, 2009). Annual chlorophyll biomass has also decreased dramatically (from 1970s-2006) and winter-spring phytoplankton bloom biomass and has decreased or in some instances not occurred (Oviatt 2004; Oviatt et al. 2002). With the weakening and changing phonology phytoplankton blooms, it is hypothesized that the rate of remineralization of nutrients in the benthos will concurrently change due to weaker benthic-pelagic coupling and that less organic matter deposition will result in fewer secondary consumers and ultimately less demersal fish (Fulweiler and Nixon 2009; Nixon et al. 2009). While research over the last 60 years have elucidated some of the correlations between the changing physical environment and phytoplankton production in Narragansett Bay, very little is known on how Block and Rhode Island Sounds have responded to the same climate trends, including with regard to primary production, respiration, and coupling between the seafloor and water column. Therefore, the time frame for the proposed baseline and monitoring research (refer to sections 2 and 4.1, respectively) should be extended. This continued data stream would build the knowledge platform necessary to document, detect, and interpret climate change impacts within the Ocean SAMP area over spatial scales ranging from ecosystem-wide to individual habitats.

4.0 Research Focused on Ocean Engineering

Ocean engineering is a critical component of offshore renewable energy (ORE) development. Establishing appropriate design, construction, and structural requirements for development is essential to ensure an energy facility reaches its maximum potential and efficiency and to anticipate development effects.

To help achieve the goals, URI has submitted a proposal to the US Department of Energy (DOE) in partnership with developers (Deepwater Wind), turbine manufacturers (Siemens Inc.), and other academic institutions (National Renewable Energy Laboratory, Massachusetts Clean Energy Center, and the State University of New York). The proposal is to study the demonstration project proposed within the Ocean SAMP (BI) REZ for designs and techniques to lower the cost of energy production from offshore wind farms. Through monitoring and modeling of the five 6MW turbines and associated support structures (jacket structures, pile foundations, submarine transmission cables), the project aims to: 1.) Conduct extensive multi-disciplinary monitoring and modeling of the BI wind facility, to optimize the construction, deployment, and operations of such projects in the future, leading to a reduced cost of energy; and 2.) Use data acquired and lessons learned to reduce the deployment timelines and uncertainties for larger commercial scale offshore wind development projects in US waters.

Research that should accompany a demonstration-scale wind facility includes:

- Design, install, and operate a buoy based observation system to make measurements of key physical parameters that characterize environmental forcing of the structure including waves, currents, winds (including measurements with elevation via buoy mounted LIDAR), and salinity and temperature in the immediate vicinity of the test turbine.
- Design and implement a passive acoustic monitoring system to monitoring ambient noise levels pre, during, and post construction (operation phase). The measurements should allow determination of noise associated with marine biologics, marine shipping, and construction (pile driving), and turbine operation.
- Instrument the foundation system to measure cyclic stresses, accumulated displacement, and pore water pressure generation in the surrounding soils. Strain gages on the piles will monitor the stresses and accumulated displacement and in situ piezometers will measure the generation of pore pressures. In the glacial silts and sands in Rhode Island Sound, possible generation of pore pressures can lead to a reduction of soil stiffness under long-term cyclic loading.
- Implement a structural health monitoring system of the lattice jacket structure by placing strain gages and accelerometers on the jacket and analyzing the data periodically and after extreme events (i.e. hurricanes) to predict on-going and future structural damage.
- Develop and implement state of the art models to predict the environmental loading and response of the structure and foundation to routine and extreme loading. Compare the model predictions to data collected from the foundation and structural monitoring systems described above.
- Perform an analysis of the power production of the selected turbine by wind direction, atmospheric stability, and wind speed and shear. Determine the capacity factor for the turbine, assess possible wake effects from adjacent turbines in the field, and compare estimates of the predicted to observed power production.
- Develop models using the existing data, measurements from the observation stations, and demonstration project, including for construction and operating noise from an

offshore wind turbine. The modeling component will develop techniques for predicting the propagation of radiated noise from the structure during construction (pile driving) and operation. Model results will be compared and validated with acoustic measurements during construction and operation.

- Perform an in depth review of the design of the wind turbine support structure and foundation proposed by DWW and the Certification Verification Agent (CVA) review of this design required by CRMC. Then, based on the modeling investigations and observations review the current design standards and make recommendations about how the standards should be revised to more accurately represent the risks.

Importance:

The proposed research would be extremely valuable for:

- Examining the structural response of wind turbine generators to extreme environmental and cyclic (fatigue) loads;
- Assessing power production and energy transfer/integration into the grid;
- Investigating currents, waves, wind loading, and seabed/sub-bottom characterization;
- Measuring acoustics generated from the facility (noise in water and air);
- Developing a comprehensive offshore wind economic modeling and analysis to compute costs of energy production under various scenarios;
- Cost savings for the offshore wind industry. This will result from better understanding of the efficiency of turbines in a wind farm, of wake effects, and of the true structural/foundation response due to environmental loads;
- An optimal design can be achieved for fatigue (the critical design case for these structures) based on accurate measurements of stiffness and damping of the structure/foundation system;
- Developing the first comprehensive data set of environmental forcing (wind, wave) and the resulting structural and turbine response of a full-scale jacket support structure. This data and the resulting analyses would be invaluable to the industry for optimizing the support structure design and designing the layout of a wind farm to minimize wake effects;
- Producing a tool to predict acoustic noise as a function of range and depth around the wind farm to help regulators to make sure that the noise is within desirable levels;
- Recommending and setting design and structure standards to ensure high performance and efficiency of turbines. Establishing engineering requirements for ORE projects within the United States is an area of active interest, for which the proposed research could offer valuable information; and
- Provide greater understanding of ORE design standards to be considered during the Ocean SAMP Certified Verification Agent (CVA) review process. In turn, this could also inform the CVA process used nationally by the Bureau of Ocean Energy Management (BOEM).

5.0 Information Framework

Adequate geospatial support for the Ocean SAMP area involves the development of a framework to facilitate organization, visualization and dissemination of information, as well as guide policy decisions and monitoring. Geospatial data and their relationships are the cornerstone of marine spatial planning; whether preparing for offshore renewable energy (ORE) or assessing vulnerability to climate change. Geographic Information Systems (GIS) provide the suite of tools to analyze and display these relationships in a manner that is useful to both researchers and regulators. Integrating resource use with scientific studies detailing the dominant biological, physical, social and ecological relationships provides managers the knowledge to develop strategies that provide needed access to resources without compromising environmental conditions. Tasks for this work are outlined below.

Data integration and consolidation. The central database developed as part of the Ocean SAMP project is the core structure for integrating and visualizing all of the research conducted throughout the 2-year process, and it is imperative that any new information collected is compatible with the existing system. The Ocean SAMP data holdings are the only multidisciplinary data source available for Rhode Island's offshore waters.

Mapping and data exchange. Access to OSAMP data currently is done through the NARRBAY.ORG website where users can download individual data sets or access data through the RI Ocean SAMP Map Viewer. These delivery outlets allow for the efficient mapping and data exchange between and among scientists, managers, and the public.

The NARRBAY.ORG website was modeled after the RIGIS website, the primary point of access to terrestrial geospatial data for Rhode Island, to access Rhode Island's coastal and marine-related data, and was developed to accommodate the rich variety of file formats. The software architecture of the NARRBAY.ORG site is now 10 years old and in need of a technology makeover. Newer technologies, such as content management systems, are now available that would make the website more efficient and easier to maintain. A redesigned NARRBAY.ORG site would be fully searchable and would integrate directly with the RIGIS system for cross-platform querying. Along with providing direct data download, the site would feature the latest news feeds for marine spatial planning and ORE development, and would house links to related regional organizations and data providers.

In addition, the EDC would leverage new efficiencies in cloud computing found within the ArcGIS.com platform, rather than develop a single map viewer, for visualizing Ocean SAMP data. The system is designed specifically for spatial data and is a cloud-based, content management system for working with geographic information. The platform provides an on-demand infrastructure for creating web maps and collaboratively sharing that information throughout an organization. There are many benefits of this model. For instance, users would be able to search the available data and build their own custom maps using the standard Ocean SAMP template, which could be saved and shared to improve collaboration. As new data are acquired they would simply be added to ArcGIS.com for immediate access.

Information access and integration within management agencies. Spatial relationships are fundamental to resource management; who, what, when, where and how the coastal environment is being used are all issues that factor into management decision-making. A GIS provides the suite of tools to analyze and display these relationships, but there is a cost in terms of the time required to obtain/maintain proficiency with the software. Oftentimes individuals accumulate some level of experience on project-specific basis, but with limited funds there is often not enough time available for a thorough review of how information is stored and disseminated throughout an organization. To mitigate these issues, the EDC is proposing to expand the in-house mapping capabilities of the CRMC, work with staff to document the GIS workflow and needs for different focus areas, and provide technical training. The implications of doing so extend far beyond the Ocean SAMP project and would continue to benefit the organization and its mission long after the immediate project has ended.

Regional collaboration. The EDC will engage appropriate regional organizations to share maps, data, and information, and encourage regional collaboration on marine spatial planning of shared coastal resources. The regional collaboration effort will target groups with missions that embrace open sharing of data and experiences.

6.0 Regional Research Initiatives

There are several regional organizations that may also be interested in research projects similar to those presented in Sections 2.0, 3.0 and 4.0 and may be potential collaborators or funders for this work.

Regional research initiatives are particularly important when studying wildlife and human uses that cover a broad geographic range. For example, to accurately understand the distribution of marine mammals, migratory birds, or fisheries activities large-scale data collection is necessary to determine the relative importance of an area for habitat or use.

The Northeast Regional Ocean Council (NROC) was created in 2005 by the six New England governors to facilitate the development and implementation of coordinated and collaborative regional goals and priorities to improve responses to issues and challenges that are inherently regional. In 2011, NROC began a two year work plan to include research initiatives for the waters surrounding the New England region related to:

- Characterizing baseline information on environmental, social and economic aspects of the region in order to inform coastal and marine spatial planning (CMSP) in the region;
- Identifying Areas for Potential Conservation in the region based on their ecological significance;
- Identifying areas in the region for future use, such as offshore renewable energy (ORE) development, or areas significant for commercial or recreational fishing;
- Develop a performance monitoring and evaluation system as part of the CMSP plan to inform plan adaptation over time; and
- Provide regional management governance structure and coordination mechanisms for integrated state, tribal and federal CMSP and decision-making.

These regional research initiatives in many ways expand and compliment the research projects presented here or the research already conducted as part of the Ocean SAMP process by providing a regional context. Having a regional perspective of the natural resources and human uses offshore is vital to understanding the relative value or importance of one area over another. Therefore, coordinating future Ocean SAMP research efforts when possible with NROC will result in a more accurate understanding of the area. Furthermore, because ORE will likely be developed across New England, collaborating on research projects focused on measuring the impact of development may help utilize limited funding most effectively.

In addition to NROC, there are other regional organizations that are potential collaborators on regional research projects. The Northeast Sea Grant Consortium (NESGC) is a partnership of all the Sea Grant organizations in the Northeast with the goal of working together to support research and outreach related to regional ocean issues. Collaborating with NESGC on research projects presented in this agenda would allow the projects to be expanded to a regional scale.

7.0 Conclusion

Since its inception in 1971, the CRMC has managed Rhode Island's coastal waters using an adaptive management approach, a systematic process for continually improving management by adjusting practices and policies as new information becomes available. This Science Research Agenda is one mechanism to ensure the Ocean SAMP is implemented using an adaptive management approach by identifying research needed to help guide scientifically sound management decisions. Specifically, the research agenda focuses on studies to:

- Provide a better understanding of baseline environmental and biological conditions;
- Identify monitoring studies to assess changes in baseline conditions due to natural and human-induced impacts;
- Advance the technology and efficiency of ORE devices; and
- Develop an information framework to effectively communicate information to researchers, regulators, developers, and the public.

Prior to the Ocean SAMP process, knowledge was limited about the natural resources and human uses of the waters off Rhode Island's coast. Today, much more is understood about this study area, in part due to the tremendous efforts conducted as part of this marine spatial planning process, including the of compilation and synthesis of existing information and collection of new data. Despite the large amount of data collected, the Science Research Agenda was created to identify where additional research is still needed to close data gaps regarding the current state of the Ocean SAMP ecosystem, the potential effects of future offshore development, and the impacts of climate change. Research agendas are valuable tools because they help to identify topics where additional study is needed. As such, agendas help to direct future funding when it becomes available, as well as facilitate collaborative, multidisciplinary research projects.

While this research agenda focuses on the Ocean SAMP study area, the research ideas expressed may be applicable for regional marine spatial planning efforts or valuable on a national scale as it relates to understanding the effects of offshore renewable energy development.

8.0 Literature Cited

Andrade, H. and Renaud, P.E., 2011. Polychaete/amphipod ratio as an indicator of environmental impact related to offshore oil and gas production along the Norwegian continental shelf. *Marine Pollution Bulletin*, 62(12): pp. 2836-44.

Auster, P.J., Heinonen, K.B., Witharana, C., and McKee, M. 2009. A habitat classification scheme for the Long Island Sound region. Long Island Sound Study Technical Report. EPA Long Island Sound Office, Stamford, Connecticut 06904: 83 pp.

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. CEFAS 2011 (in press) http://www.neamap.net/publications/VIMS_NEAMAP_Peer_Review_Documents.pdf

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

CEFAS. 2004. Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements.

Degraer, S., Brabant, R., and Rumes, B. (Eds.). 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: 157 pp. + annex. Available online: http://www.mumm.ac.be/Downloads/monwin_report_2011_final.pdf (Last accessed 4/4/2012).

Durbin, E.G., Campbell, R.G., Casas, M.C., Ohman, M.D., Neihoff, B. Runge, J., and Wagner, M. 2003. Interannual variation in phytoplankton blooms and zooplankton productivity and abundance in the Gulf of Maine during winter. *Marine Ecology Progress Series*. 254: pp. 81-100.

Fisher, J., Frank, K.T., Kostylev, V.E., Shackell, N.L., Horsman, T., and Hannah, C.G. 2011. Evaluating a habitat template model's predictions of marine fish diversity on the Scotian Shelf and Bay of Fundy, Northwest Atlantic. *ICES Journal of Marine Science*, 68(10): pp. 2096-2105.

Freidland, K. D., Hare, J.A., Wood, G.B., Col, L.A., Buckley, L.J., Mountain, D.G., Kane, J., Brodziak, J., Lough, R.G. and Pilskaln, C.H. 2008. Does the fall phytoplankton bloom control recruitment of Georges Bank haddock, *Melanogrammus aeglefinus*, through parental condition? *Canadian Journal of Fisheries & Aquatic Science*. 65: pp. 1076-1086.

Fry, B. 1988. Food web structure on Georges Bank from stable C, N and S isotopic compositions. *Limnology and Oceanography*. 33 (5): pp. 1182-1190.

Fulweiler, R.W., Nixon, S.W., Buckley, B.A., and Granger, S.L. 2007. Reversal of the net nitrogen flux in coastal marine sediments. *Nature.* 448: pp. 180-182.

Fulweiler, R.W. and Nixon, S.W. 2009. Responses of benthic–pelagic coupling to climate change in a temperate estuary. *Eutrophication in Coastal Ecosystems.* 290: pp. 147-156.

Garrison, L.P. and Link, J.S. 2000. Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. *Marine Ecology Progress Series.* 202: pp. 231-240.

Global Insight. 2008. *Rhode Island Tourism: Strength in a Difficult Time: 2007 Tourism Satellite Account.*

Grilli, A.R., Lado T., and Spaulding, M.L. 2012. A protocol to include ecosystem services in a wind farm cost model. Journal of Environmental Engineering (Under press/ online from June 29, 2012).

Hansson, S., Hobbie, J.E., Elmgren, R., Larsson, U., Fry, B., and Johansson, S. 1997. The stable nitrogen isotope ratio as a marker of food-web interactions and fish migration. *Ecology*. 78 (7): pp. 2249-2257.

Head, E.J.H., Brickman, D. and Harris, L.R. 2005. An exceptional haddock year class and unusual environmental conditions on the Scotian Shelf in 1999. *J. Plankton Res.* 27: pp. 597-602.

Hyslop, E.J. 1980. Stomach contents analysis – a review of methods and their application. *Journal of Fish Biology*. 17 (4): pp. 411-429.

Jolly, G.M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences.* 47 (7): pp. 1282-1291.

LaFrance, M., Shumchenia, E., King, J., Pockalny, R., Oakley, B., Pratt, S., and Boothroyd, J. 2010. Benthic Habitat Distribution and Subsurface Geology Selected Sites from the Rhode Island Ocean Special Area Management Study Area. Technical Report 4. 99 pp; Kingston, RI, University of Rhode Island. Available online: http://seagrant.gso.uri.edu/oceansamp/pdf/appendix/04-LaFrance_et_al_SAMPreport.pdf (Last accessed 3/10/2012).

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.

Malek, A.J., LaFrance, M., Collie, J., and King, J. 2010. Fisheries ecology in Rhode Island and Block Island Sounds for the Rhode Island Ocean Special Area Management Plan 2010. Technical Report 14. 56 pp; Kingston, RI, University of Rhode Island. Available online: http://seagrant.gso.uri.edu/oceansamp/pdf/appendix/14-Maleketal_RISAMP.pdf (Last accessed 3/10/2012).

Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki, B.L. and Henry, K.W. 2009. The impact of changing climate on phenology, productivity, and benthic–pelagic coupling in Narragansett Bay. *Estuarine, Coastal and Shelf Science*. 82: pp. 1-18.

Oumeraci, H., Jensen, J., Gönnert, G., Pasche, E., Kortenhaus, A., Naulin, M., Wahl, T., Thumm, S., Ujeyl, G., Gershovich, I., and Burzel, A. 2009. Flood risk analysis for a megacity: The German XtremRisK project. *Proc. Conference on Road Map towards a Flood Resilient Urban Environment*, Paris, France: pp. 8.

Oviatt, C.A., Keller, A. and Reed, L. 2002. Annual Primary Production in Narragansett Bay with no Bay-Wide Winter–Spring Phytoplankton Bloom. *Estuarine, Coastal and Shelf Science*. 54: pp. 1013-1026.

Oviatt, C.A. 2004. The Changing Ecology of Temperate Coastal Waters During a Warming Trend. *Estuaries*. 27(6): pp. 895-904.

Paton, P.W.C., McWilliams, S.R., Winiarski, K.J., and Trocki, C.L. 2010. The Spatial Distribution, Abundance, and Flight Ecology of Birds in Nearshore and Offshore Waters of Rhode Island. Technical Report 11. Kingston, RI, University of Rhode Island. Available online: http://seagrant.gso.uri.edu/oceansamp/pdf/appendix/11a-PatonAvianRept.pdf (Last accessed 3/10/2012).

Pershing, A.J., Greene, C.H., Jossi, J.W., O'Brien, L., Brodziak, J.K.T. and Bailey, B. 2005. Interdecadal variability in the Gulf of Maine zooplankton community, with potential impacts on fish recruitment. *ICES Journal of Marine Science*. 62: pp. 1511-1523.

Platt, T., Fuentes-Yaco, C. and Frank, K.T. 2003. Spring algal bloom and larval fish survival. *Nature*. 423: pp. 398-399.

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.

Rhetore, P.E., Fuglsang, P., Larsen, G., Buhl, T., Larsen, T.J. and Madsen, H.A. 2011. TopFarm: Multi-fidelity optimization of offshore wind farm. In *Proc. 20th Intl. Offshore and Polar Engng. Conf.* (Maui, Hawaii, USA, June 19-24).

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J.G., and Krause, J. 2012. Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. *Ecological Indicators*, 12(1): pp. 174-184.

Rhode Island Coastal Resources Management Council (RI CRMC). 2010. Rhode Island Ocean Special Area Management Plan. Adopted October 19, 2010. Kingston, RI, University of Rhode Island. Available online: http://seagrant.gso.uri.edu/oceansamp/documents.html (Last accessed 5/21/12).

Saunders, G., Bedford, G.S., Trendall, J.R., and Sotheran, I. (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

Smith, L.M., Whitehouse, S. and Oviatt, C.A. 2010. Impacts of climate change on Narragansett Bay. *Northeast Naturalist*. 17(1): pp. 77-90.

Spaulding, M.L., Grilli, A.R., 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): pp. 8-23.

Steele, J.H. 2001. Network analysis of food webs: pp. 1870-1875.

Thunberg, E. 2008. Trends in Selected Northeast Region Marine Industries. Woods Hole, MA: National Oceanic and Atmospheric Administration Northeast Fisheries Science Center, July 2008.

Tyrrell, T. J. and Johnston, R.J. 2001. A framework for assessing direct economic impacts of tourist events: distinguishing origins, destinations, and causes of expenditures. *Journal of Travel Research*, 40: pp. 94-100.

Van den Eynde, D., Brabant, R., Fettweis, M., Francken, F., Melotte, J., Sas, M., Lancker, V.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., 2010. Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability. pp. 19-36.

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., Degraer, S., Schelfaut, K., Willems, W., and Van Lancker, V., 2009. A protocol for classifying ecologically relevant marine zones, a statistical approach. *Estuarine, Coastal and Shelf Science*, 83(2): pp. 175-185.

Wiley, D.N.; Moller, J.C.; Zilinskas, K.A. 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.