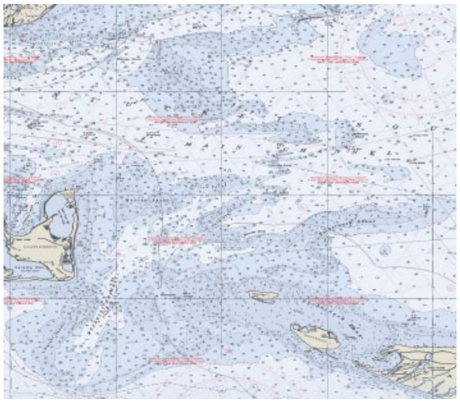
Marine Megavertebrates and Fishery Resources in the Nantucket Sound – Muskeget Channel Area

Assessing Impacts of Marine Renewable Energy Installations on Marine Megavertebrates - Recommendations for the Proposed Muskeget Channel Tidal Energy Project



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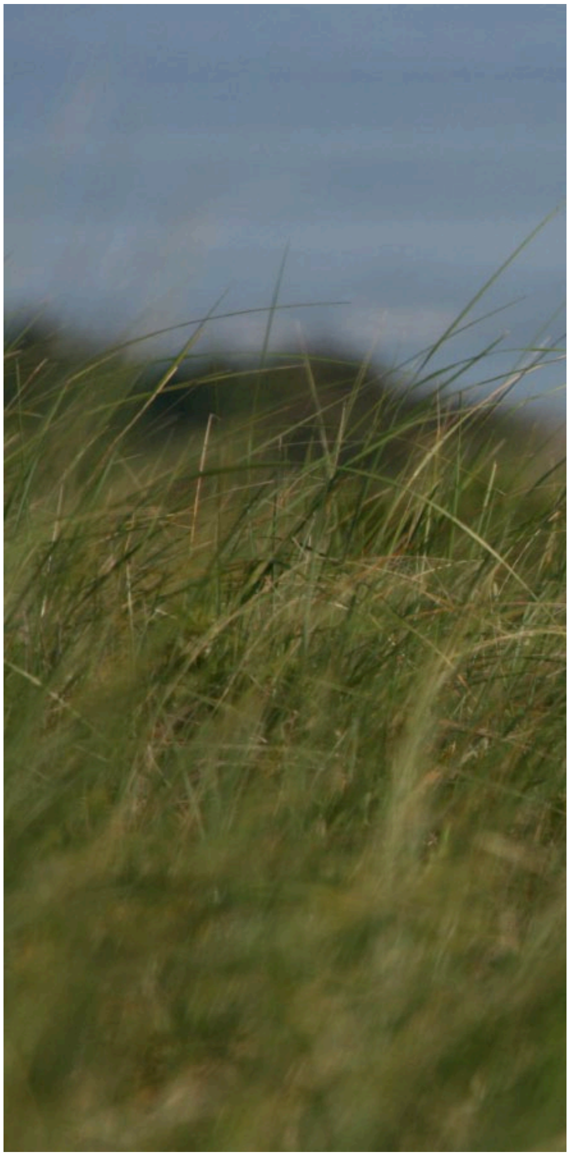

A Report to

Harris Miller Miller & Hanson Inc

for HMMH Project # 303910

Environmental Impacts of Sediment Transport Alteration and Impacts on Protected Species: Edgartown Tidal Energy Project

Funding provided by the

U.S. Department of Energy

under Grant # DE-EE0002656

September 2010

Cover Images: Chatham fishing boats, O. Nichols; Right whale, Provincetown Center for Coastal Studies image taken under NOAA permit 633-1763, with authority of the U.S. Endangered Species Act

Figures 2.1, 2.2, 2.13, 2.14, 2.15, 2.16 created by Battelle

This report should be cited as:
Leeney, R.H., Nichols, O.C., Sette, L., Wood LaFond, S. and Hughes P.E.2010. Marine Megavertebrates and Fishery Resources in the Nantucket Sound – Assessing Impacts of Marine Renewable Energy Installations on Marine Megavertebrates – Recommendations for the Proposed Muskeget Channel Tidal Energy Project. Report to Harris Miller Miller & Hanson Inc., September 2010. Provincetown Center for Coastal Studies, Provincetown, MA, USA. 24 pp.
Available at: www.coastalstudies.org

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Executive Summary

This report draws on the body of environmental assessment work done on marine renewable energy installations (MREI) in other regions, particularly in Europe, and summarized in a companion report – Ecology and Effects of Marine Renewable Energy Installations. A combination of several techniques is required in order to appropriately monitor marine megavertebrate species around tidal turbine sites; these techniques are reviewed, and some of the particular challenges of monitoring at tidal turbine sites are identified.

A methodology plan specific to the proposed tidal energy project for Muskeget Channel by the Town of Edgartown is outlined in this report. This methodology plan is based on accepted survey and mitigation techniques, previous research and practical experience at other MREI sites and established, good scientific practice.

1 Background

Muskeget Channel is located between the islands of Martha's Vineyard and Nantucket. Water depths in the channel range between 40 and 160 feet, with Wasque Shoals to the west and Mutton Shoal to the east. Muskeget Channel allows for the exchange of water between Nantucket Sound to the north and the Atlantic Ocean and continental shelf to the south.

The Town of Edgartown is proposing to develop an initial 5MW tidal energy pilot project in Muskeget Channel. Edgartown holds a Preliminary Permit from the Federal Energy Regulatory Commission (FERC), giving it the exclusive right to explore the development of the resource for energy. Edgartown is required to submit a Draft Pilot License Application that will allow the town to deploy, operate and monitor this pilot-scale turbine installation. This application must include information on initial consultation with cooperating federal resource agencies; draft study plans, including one on protected species, and an outline of work that will be completed during deployment of the pilot project.

The Town of Edgartown engaged Harris Miller Miller & Hanson (HMMH) as its Principal Investigator (PI) and program manager. HMMH was successful in obtaining U.S. Department of Energy funding for the study: *Environmental Effects of Sediment Transport Alteration and Impacts on Protected Species: Edgartown Tidal Energy Project.*

The Provincetown Center for Coastal Studies (PCCS) is one of four organizations working on this study under the direction of HMMH. The PCCS tasks were to:

1. Conduct a literature review of
   - current information on the documented occurrence and habitats of marine megavertebrates – cetaceans, pinnipeds, turtles, basking sharks and sunfish – in the Muskeget Channel region;
   - documented distribution of fishery resources and habitats and commercial and recreational fishing activity;
   - studies and assessments on the environmental impacts of marine energy conversion projects on marine megavertebrates.
2. Prepare protocols for environmental studies and monitoring of marine megavertebrates specific to Muskeget Channel sufficient to collect data needed to define baseline conditions and evaluate impacts from the operation and maintenance of the tidal energy project.
3. Prepare a synthesis report on the permitting and planning framework for marine energy conversion projects, focusing on the Muskeget Channel region.

This report includes work PCCS completed under Task 2. Work completed under Task 1 and Task 3 is presented in separate reports.

Photo: Atlantic white-sided dolphin, E. Bradfield

2 Methods for Assessing Impacts of Marine Renewable Energy Installations on Marine Megavertebrates

2.1 Introduction

In designing environmental monitoring protocols for sites of proposed MREIs, no single standard will be universally applicable. The survey techniques, size of the study area, design and duration of the survey will all depend upon the area itself, the species found there and their conservation status, the nature and scale of the planned MREI and the duration of the construction period. As highlighted in Inger et al. (2009), a systematic review of previous experience and studies in the field of impact assessments for MREIs (as provided in Section 5) combined with solid study design are key to appropriately assessing the impacts of MREIs.

Since the Muskeget Channel project is one of nine tidal turbine sites proposed for the U.S. East Coast and the larger region is a proposed research site for MREIs (Northeast Offshore Renewable Energy Innovation Zone, NOREIZ), it will be essential for this project to set a precedent for exemplary environmental monitoring protocols. This report outlines methods for monitoring marine megavertebrate populations and for documenting spatio-temporal variation in patterns of habitat use and behavior. It then provides a set of objectives for monitoring the impacts to marine megavertebrate populations, specific to the Muskeget Channel MREI project to insure that no significant impacts occur to any marine megavertebrate populations in the region. A recommended methodology plan is outlined.

Tidal Turbine Sites: A Unique Challenge

A combination of several techniques is required to appropriately monitor marine megavertebrate species around tidal turbine sites. Visual data collection for marine megavertebrates involves frequent boat-based surveys and/or aerial surveys, and these techniques are more suitable for some species (e.g. turtles, cetaceans) than for nonair-breathing species such as basking sharks. The use of Static Acoustic Monitoring (SAM) at offshore wind farm sites is now standard practice in many areas (e.g. Tougaard et al., 2004; Carstensen et al., 2006). This method facilitates long-term monitoring; however, it is also more suitable for some species (e.g. odontocetes) than others. A number of issues, detailed below, will likely arise with the use of this method at tidal sites. Proposed sites for tidal power developments will present a very specific and unique set of challenges for monitoring. Environmental monitoring methods for marine megavertebrates can be very difficult to carry out in tidally dynamic areas, as the very nature of these sites dictates that they are characterized by strong tides and complex oceanographic features.

Environmental monitoring methods also demand considerable forays into new areas such as the investigation of underwater behavior of megavertebrates around turbines, the development and testing of new moorings for submersible instruments and SAM capabilities and limits in extremely high-flow environments.

2.2 Outline of Survey Methods for Marine Megavertebrates

2.2.1 Visual Survey Platforms

Visual surveys (aerial and/or boat-based) are an accepted and well-established methodology for assessing abundance and distribution of most cetacean species. Such platforms allow for the collection of valuable species presence information for less common cetacean species or those for which acoustic monitoring is not yet well-developed. By using **Distance sampling** methodology (Buckland *et al.,* 2001), which is the accepted means of generating absolute abundance estimates for these species, region-specific abundance estimates can be calculated. In order to be useful, Distance sampling surveys must be carried out frequently and according to a strict survey design with even coverage throughout the study area.

Aerial surveys are an effective means of covering large study areas within a manageable period of time. They are also less weather-dependent than boat-based surveys, although detection probabilities, especially for smaller species such as harbor porpoises, are affected by higher sea states just as for shipboard surveys (Palka, 1995; Teilmann, 1995).

Aerial surveys are well-established as an acceptable method for surveying for cetaceans (e.g. SCANS I & II; Hammond *et al.,* 2002), seals (e.g. Matthiopoulos *et al.,* 2004; Cronin *et al.,* 2006) and turtles (e.g. Marsh & Saalfeld, 1989; Jean *et al.,* 2010), and they have also been used to assess relative or "apparent" abundance of fish species such as basking sharks and sunfish (Leeney *et al.,* in review; Houghton *et al.,* 2006; Campana *et al.,* 2008). In fact, for basking sharks and species such as right whales, which can spend long periods of time just beneath the water surface rendering them invisible to vessel-based observers, aerial surveys can be an excellent means of detection. This method can also be used to collect valuable photo-identification data on endangered species such as the North Atlantic right whale (e.g. Leeney *et al.,* 2008, 2009).

2.2.2 Static Acoustic Monitoring (SAM)

Acoustic monitoring is becoming widely accepted as an efficient way to collect valuable long-term datasets on cetacean habitat use for EIS purposes (e.g. Teilmann *et al.,* 2002; Carstensen *et al.,* 2006; Tougaard *et al.,* 2009; Thompson *et al.,* 2010). Diederichs *et al.* (2009) reported that SAM using T-PODs (the predecessors of C-PODs) or other devices provides good data on harbor porpoises, and potentially other odontocete species, at a high temporal but low spatial resolution. Deploying several SAM devices in the area of interest overcomes the issue of spatial resolution. Statistical analysis from areas with low and high porpoise densities proved that a 30% change in harbor porpoise presence can be proved with a sample size of 3-11 SAM units (Diederichs *et al.,* 2009). The initial baseline data review should inform, to a great extent, the choice of acoustic monitoring technique to be used. The species present, their detectability using acoustic techniques and how necessary it is deemed to have fine-scale data on spatio-temporal patterns of habitat use of particular species should all factor into the choice of acoustic monitoring tool.

C-PODs are only suitable for monitoring cetacean species which use echolocation. They have been used extensively to monitor spatio-temporal patterns of habitat use for many species of odontocetes including harbor porpoises (e.g. Tougaard *et al.,* 2009) and bottlenose dolphins (e.g. Leeney *et al.,* 2007; Philpott *et al.,* 2007). Autonomous seafloor recording units, referred to as "pop-ups," are considerably more expensive and complex to deploy. They are used to collect data on vocalizations from baleen whales such as North Atlantic right whales (Clark *et al.,* 2010).

SAM at tidal energy sites will present a number of unique challenges that will need to be addressed in order to effectively collect, analyse and interpret the data collected by this means.

- **Moorings for SAM equipment** present a very specific challenge in areas where tidal turbines are planned, since the characteristics of these areas necessarily pose a risk that gear will move or be swept away. Moorings need to be flexible but extremely resilient to deal with the dynamic nature of this environment.

- **Noise-modelling** specific to a given site will need to be conducted. Tidally dynamic areas are high-noise areas since there is both water moving at high speeds and transfer or movement of bottom sediment. Noise-modelling will provide an understanding of the acoustic environment so that the detectability of various species, the range at which they can be detected and the variability in those parameters with temporal and environmental conditions can be well understood and incorporated into any analysis of SAM data.

- **Background research** on the species likely to be encountered in the region, as well as the types of vocalizations each species produces, will be essential in order to first select the most appropriate SAM technology to be used in the area and then to interpret the data collected. There is a paucity of data on vocalizations, especially echolocation, of many cetacean species.

- **Focal studies** are needed on certain species for which data are lacking. Such studies should be carried out prior to commencement of monitoring and should involve direct hydrophone recordings of the vocalizations of the target species in concert with data collection on group size and behavior.

- **Calibration of SAM equipment** will be essential to insure that the outputs are comparable between units and/or sites. The assumption should not be made that all units, even of any one design, have identical sensitivities and detection functions unless this is guaranteed by the manufacturer. On a wider scale, there is a great need for a detailed comparison of various pieces of acoustic monitoring equipment to be made. This will allow for rates of detection, habitat use, activity and behaviors to be compared between projects and over much wider regions.

2.2.3 Visual Surveys from Platforms/land

Land-based counts of hauled-out seals (pinnipeds) have been used extensively as a means of calculating population size and patterns of habitat use (e.g. Pomeroy *et al.,* 2005; Leeney *et al.,* 2010). Relative to other methodologies for studying marine mammals, it is a safe and easy method. Numbers of seals hauling out also varies with season, and so counts throughout the year will provide data on this seasonal pattern.

Visual surveys, from both land-based sites and at-sea platforms, provide site-specific data on temporal variation and can also provide the opportunity to collect useful data on surface behaviors. By carrying out visual surveys at a range of tidal states and times of day over several years, a fuller understanding of the temporal patterns of habitat use specific to a site can be gained. This, combined with data on species which might be inclined to dive or swim in the vicinity of tidal turbines or which appear unable to detect the moving turbines underwater from a safe distance, can then lead to an assessment of "high risk" species and time periods (e.g. seasons, states of tide, times of day) of greatest collision risk. Behavior sampling can be carried out using Ad Libitum or Focal-Animal sampling techniques (Altmann, 1974), depending on the context, and should likewise be collected in a range of conditions and in both impact and control situations.

Table 1: Operational Objectives for the Muskeget Tidal Turbine Environmental Monitoring and Mitigation Program

ELEMENT	OBJECTIVE	MEASUREMENT
Marine mammals (general)	Required: No marine mammal mortalities (directly or indirectly as a result of a non-fatal injury) occur as a consequence of physical interaction with the turbine rotors.	1. Post mortem evaluation of carcass strandings and assessment of cause of death. 2. Investigation of any carcasses sighted during aerial surveys. 3. Health assessment of large whales during aerial surveys; collection of observational data on seal condition during haul-out counts. 4. Platform-based observations*/video[§] of behavior near turbines, if possible.
	Recommended: Establishment of an active sonar system which detects marine megavertebrates at sufficient range from the turbine to allow a precautionary shutdown to occur automatically [a].	1. Number of sonar detections and shutdown events. 2. Matching of sonar detections to platform-based sightings for species identification, where possible.*
	Relative abundance of marine mammals in Muskeget Channel is not significantly modified by the operation of the turbines.	1. Assessment of abundance and distribution in control and impact sites, before, during and after construction. An adequate baseline ("before") dataset would comprise two years of data. 2. Statistical comparison of patterns of variation in abundance and distribution (aerial, haul-out and platform-based* counts). 3. Similar comparison of hauled-out seal counts in the region over the same time scale.
	Sub-surface noise generated by the turbines does not cause a level of disturbance to marine mammals sufficient to displace them from areas important for foraging and social activities.	1. Measurement of zone of audibility and zone of disturbance at full power operation; description of noise environment. 2. Assessment of overlap of augmented (with turbine operation) noise environment with vocalization and hearing frequency ranges of most common species (and species of key interest). 3. Number of marine mammals underwater sighted in close proximity (~ 50 m) to the turbines per hour (if possible, from platform or imaging techniques) [b].
	Recommended: The turbines operate in such a way as to stop when marine mammals are within 50 m of the rotors.	1. Assessment of the (combined) surface*, underwater[§] (and sonar) detection events with automatic shutdown when a mammal is within 50 m of turbine rotors. 2. Post mortem evaluation of carcass strandings/sightings and assessment of cause of death.

Marine mammals: Pinnipeds (seals)	The turbines do not cause a significant change in the use of important seal haul-out sites within or adjacent to the region.	Haul-out site seal numbers from aerial surveys and haul-out site counts [b].
	Seals are not excluded from important foraging habitat or social areas within the Muskeget Channel area as a result of the installation and operation of the turbines.	Comparison of sightings frequency over space and time (from haul-out site counts and aerial survey data) in pre-operational, construction and operational periods [b].
	The number of harbor and gray seal adults and pups does not decline significantly as a result of the installation and operation of the turbines.	Population estimates derived from aerial survey and haul-out counts to establish baseline data for "local" populations. Estimates to be set within the context of historical data.
Marine mammals: Cetaceans (whales and dolphins)	Cetaceans are not excluded from important foraging habitat or social areas within the Muskeget Channel area as a result of the installation and operation of the turbines.	1. Abundance and distribution (from aerial survey data) in pre-operational, construction and operational periods. 2. Comparison of SAM data between before and after construction/operation and in control and impact sites. SAM data may also provide indices of behavior (e.g. assessment of buzz train production rate associated with feeding).
	The turbines do not displace cetaceans from the immediate region or adjacent areas.	1. SAM data analysis at a range of scales. 2. Sighting data from platform-based observers if possible.
Basking sharks & sunfish	No mortalities of basking sharks or sunfish (directly or indirectly as a result of a non-fatal injury) occur as a consequence of physical interaction with the turbine rotors.	1. Post-mortem evaluation of carcass strandings and assessment of cause of death. 2. Investigation of any carcass sighted during aerial surveys.
	The turbines do not cause a significant change in habitat use by these species.	1. Comparison of sightings frequency over space and time (from aerial survey data) in pre-operational, construction and operational periods).
Turtles	The turbines do not injure or displace turtles from areas they might otherwise utilize.	1. Post-mortem evaluation of carcass strandings and assessment of cause of death. 2. Comparison of sightings frequency over space and time (from aerial survey data) in pre-operational, construction and operational periods).
Seabirds	The turbines do not injure or displace foraging diving birds from important areas within Muskeget Channel.	1. Sightings frequency of diving and rafting birds as well as behavior data from platform-based*, video[§] and/or aerial surveys [c].

a. The SeaGen turbine in Strangford Lough uses a sonar device to detect marine mammals close to the turbine and to instigate shutdown (Bedford & Fortune, 2010). An initial period with a similar system at the Muskeget site is recommended, if possible, to collect data on initial avoidance/ approach by various species.

b. At the SeaGen site, seals were satellite tagged and the resulting telemetry data provided supplementary information as to how individuals were using the site both before and during operation of the turbine. Although expensive, telemetry can provide extremely useful insights into changes, or lack thereof, in habitat use by marine mammals.

c. Injured or dead birds will be difficult to detect and impossible to assess from aerial survey platforms. The best way to detect collision victims for this species group would be from a platform among the turbines; in the absence of this, a submerged camera on one or more turbines could be trialled (see **Methodology Plan** section).

* If platform-based, at-sea observations are possible for the Muskeget project.

§ If underwater video/sonar imaging methods prove possible for the Muskeget project

2.3 Environmental Risk Thresholds

In working to meet the above objectives, it will be essential to define the terms "significant change/ modification" and "significant decline," for the purposes of conservation management. Firstly, the change must be detected. This will be achieved using an appropriate sampling design and monitoring techniques. The magnitude of the change having been evaluated, it must be attributed either to an effect of the MREI or to something else. Finally, the magnitude of the change must be set in the context of local, regional and national trends in abundance and distribution in order to determine whether such a level of change is considered significant for a population. That is, are the effects likely to be long-term or to be of detriment to the population of a whole? EMEC (2008) provide a table detailing the criteria to be used to assess potential and residual environmental impacts, including both ecological and socio-economic effects, which may prove a useful reference in addressing the above issues.

Similarly, the use of the term "important" in reference to habitat areas for marine mammals also requires definition. In this case, if a species is rare (e.g. North Atlantic right whale) or locally rare (such as a species at the limit of its range) and is found to utilize the habitat at all, or if it is numerous but large numbers (a percentage of the regional population should be defined here) utilize the habitat at least seasonally, the area should be considered important. **For all cetacean and pinniped species, it will be necessary to refer to the US Endangered Species and Marine Mammal Protection Acts for guidance relating to the significance of a given impact at the individual, community and population level.**

It should also be noted that the detection of significant change does not necessarily signify a negative effect of the turbine installation. Some changes to the area may benefit marine megavertebrates and may support greater levels of habitat use; these will nonetheless be important to document. However, natural and cyclical variations in the environment should be accounted for within the survey design and thus should not be a source for significant differences between datasets.

3

Methodology Plan for Proposed Muskeget Channel Tidal Energy Project

Photo: Humpback whale, E. Bradfield

Table 1 outlines the objectives to be achieved by the monitoring and mitigation program for the proposed Muskeget Channel tidal energy project. The methods to be used to address these objectives are detailed below. This methodology plan is based on accepted survey and mitigation techniques, previous research and practical experience at other MREI sites and established, good scientific practice. Reference has been made to the Environmental Impact Assessment guidelines developed by the European Marine Energy centre (EMEC, 2008). Modification of the advised methodology will result in reduced certainty of any detected "effect" of the MREI development on the ecology and welfare of the marine megavertebrates in the region. In addition to the "recommended" methods for detection and monitoring of marine megavertebrates, several "advised" methodologies have been included as a means of generating higher-quality data and furthering our understanding of the effects of tidal turbines on the biodiversity at this site.

3.1 Study Design

A scientifically sound monitoring design is essential to accurately detect potential impacts when monitoring changes associated with conservation management (Underwood, 1994, 1995). As a case in point, although terrestrial wind farms have been in place for several decades, their impacts on bird populations remain unclear. Some studies have suggested negative impacts on local avian populations (e.g. Langston and Pullan, 2003; Garthe and Huppop, 2004; Pearce-Higgins *et al.,* 2008). However, in a recent review of such assessments, Stewart *et al.* (2007) propose that evidence for determining the effects of wind farms is lacking, largely due to short time scales of previous studies and methodological weaknesses such as lack of replication or control sites.

As highlighted in Inger *et al.* (2009), a solid study design is crucial to understanding the true impacts of any MREI. For impact studies in relation to offshore wind farms, a BACI (Before-After/Control-Impact) design has been recommended (Diederichs *et al.,* 2009). A BACI design adds power to EIA monitoring by providing comparative datasets for the area prior to any construction or operation (i.e. a baseline) as well as during construction and/or operation at the planned MREI site and at an area outside the zone of impact. It thus incorporates and reflects the effects of any natural cycles or additional impacts in the area unrelated to the impact of the MREI.

However, while BACI study design provides the conceptual framework within which to detect anthropogenic effects, there are many practical problems associated with detecting human influences on population abundance and distribution. One main issue is that the temporal variance of many populations is great; that is, abundance data for any given population in a given area, particularly for highly mobile marine megavertebrates, is very "noisy." Thompson *et al.* (2010) documented a response by harbor porpoises to wind turbine installation activities using SAM. Their findings highlighted the fact that uncertainty regarding cetacean distribution and the scale of disturbance effects limits the effectiveness with which BACI studies can be interpreted. Another key issue is that temporal patterns in regional abundances of a given species are rarely the same from one place to another.

These two problems create difficulties in identifying unusual patterns of change in what is already a very interactive and variable measurement. The power to accurately detect such changes due to anthropogenic effects can be significantly increased by using **asymmetrical design**. That is, using one impacted site and several control locations (Underwood, 1994). The incorporation of more than one control site is key because there will be different temporal patterns at different sites, and in a comparison of the impacted site with only one "control," there is the possibility that the two sites will have very different patterns of variation. This would results in a *false positive* – an apparent effect of construction or operation when there is no actual effect – which could cost a developer time, money or even the entire project. By investing in a comprehensive **"beyond BACI" design** sampling framework, the developer will be compensated by a vast reduction in the risk of false positive results and will insure that any effects detected are fully understood and can be put into an ecosystem context.

Planning ahead of time is essential to the implementation of an effective environmental impact assessment. Diederichs *et al.* (2009) suggest that impact studies on offshore wind farms should ideally comprise two years of "before impact" data, the construction period itself and at least two years of the operational phase. The authors advise that if longer-lasting effects are detected, the study should be extended during the operational phase.

3.2 Methods

Aerial Surveys (Recommended)

Aerial surveys will enable the detection of most marine megavertebrate species of interest – cetaceans, seals and turtles. Sunfish and basking sharks may be seasonally detectable, depending on water temperature and other conditions. Aerial surveys should cover not only the offshore proposed study site and at least two control sites (beyond-BACI design), but also all known nearby seal haul-out areas (South Monomoy Island, Muskeget Island, Wasque Shoal, Great Point Nantucket and Nantucket Harbor), so that the number of seals on land can be assessed.

***Recommended frequency**:* Two per month, per site

***Recommended methodology**:* Distance sampling (Buckland *et al.,* 2001). This will generate abundance estimates within the study area and will thus enable a more accurate assessment of any effect of construction or operation within a BACI-structured study design. Aerial surveys of seal haul-out sites do not require transect methodology and would thus be best placed at the start or end of a survey flight or run as a separate flight. Seal haul-out surveys may need to employ photography and generate counts from post-survey photo analysis.

Communication with local right whale aerial survey teams (PCCS and NEFSC) will be extremely useful in ascertaining whether any injured right whales are observed in adjacent areas. Data collected within the Muskeget Channel area can also supplement the data collected by the teams, since this region currently falls outside of the focal study areas of both teams but is, nonetheless, of considerable interest for this species. During the 2010 PCCS right whale monitoring season, right whales were sighted in the Rhode Island Sound area adjacent to Muskeget Channel, thus it is likely that some individuals utilized these waters (T. Cole, *pers. comm*., May 2010).

If, during the Distance sampling protocol aerial surveys for the Muskeget project, right whales are sighted in either control or impact sites, it is recommended that the sighting be passed immediately to both teams, whereupon they can arrange, if practical, for a second flight in the area to collect detailed photo-identification data on the individual right whales utilizing this habitat. This will be of benefit not only to the New England Aquarium North Atlantic Right Whale Catalogue and the scientific community's overall understanding of the ecology of this species, but it will also provide additional data for the Muskeget team on the proportion of this endangered population using the installation area. This in turn will inform how best to mitigate for potential disturbance effects to this species, which will require special consideration.

Safety is a key concern for aerial surveys of marine megavertebrates; surveys generally utilize small aircraft and operate at low altitudes (750 ft recommended). It is advisable to follow a comprehensive safety protocol such as that prepared for PCCS (Leeney and Chronic, 2010).

Vessel Strikes: U.S. Federal law and Massachusetts state law prohibit any vessel from approaching a right whale closer than 500 yards unless permitted by NMFS (some limited exemptions). All vessel traffic associated with the construction and development of the tidal turbines should be made aware of these regulations, and a reporting scheme should be set up for these vessels, with particular emphasis on the sighting of right whales. An awareness campaign for boaters (both recreational and other) using the Muskeget Channel area might also be of benefit. Discussions should also take place to determine whether an immediate shut-down of turbines should be effected if and when right whales are detected within a given distance from the turbines.

Acoustic Monitoring (Recommended)

It is important to first characterize the acoustic environment, or background, over which cetaceans will be producing vocalizations. Ongoing acoustic monitoring at control and impact sites will allow for the description of patterns of habitat use by odontocetes (dolphins and porpoises), mysticetes (baleen whales) or both, depending on the SAM system used. A third effort involving targeted sampling from specific odontocete species is recommended to strengthen the later analyses of SAM data.

Acoustic environment monitoring

Mapping the "soundscape" of the site, i.e. measuring the zone of audibility and the zone of disturbance at full power operation and describing the full spectrum of frequencies and noise levels produced and the variability therein with different conditions (e.g. sea state, weather) is important to be able to separate "background" noises from those of odontocetes. This will allow for a detection of change in the acoustic environment with the installation of the turbines and of potential acoustic threats to marine megavertebrates as a result. These measurements will facilitate the fine-tuning of SAM for cetaceans by creating a good understanding of the "background noise" and variations therein, over which cetacean vocalizations will have to be detected.

***Recommended methodology**:* Use of a broadband frequency hydrophone at both the impact and control areas to collect information on the type of background noise that is usual. Replicate samples should be collected at a range of tidal states (slack tide and at a range of ebb and flood speeds) in all months of the year or, at the very least, during spring tides or the days leading up to peak spring tide, when the environment will be noisiest. Sampling should occur about a kilometer up- and downstream of the intended turbine deployment location, and the sampling regime should be repeated both before and after the installation.

Recording for some distance away from the exact location provides a description of the receiving environment. Ideally this work should be carried out in standardized conditions. If there is considerable ferry or working boat traffic in the area, this makes the task more difficult. Other inconstant noise sources also need to be considered.

***Equipment**:* The use of SAMS drifting ears is recommended. These recorders summarize the soundscape at frequencies from 50 Hz to 46 kHz and allow the representation of these data in map format for the site (developed by the Scottish Association of Marine Scientists and used by EMEC, Scottish Power Renewables, Scottish Government and OpenHydro in the U.K. and North America). Higher frequency recordings using a hydrophone could be carried out in parallel from the vessel used to deploy and recover the drifters.

***Challenges**:* Moored hydrophones in high-flow areas present considerable problems. At peak flow rates, which are the periods of greatest interest and also likely of highest collision risk for megavertebrates, recording needs to be free of noise generated within the hydrophone. Since flow noise associated with the passage of water around a hydrophone unit increases with flow speed, this issue is difficult to resolve.

***Safety**:* Working at sites of high tidal currents is challenging even in good weather conditions. A moderate wind against a running tide can present dangerous conditions which pose a risk to personnel and also may cause the loss of equipment. Any boat-based sampling must be carried out according to a strict safety protocol and only in ideal conditions.

Static Acoustic Monitoring (SAM)

All odontocetes studied to date appear to produce echolocation clicks as a means of searching for prey, exploring their environment and possibly for inter-species communication. A study by Akamatsu *et al.* (2007) documented an almost continuous use of echolocation by wild, tagged harbor porpoises; less than 4 % of the tagged time comprised silent periods lasting more than 50 seconds. This behavior makes species such as the harbor porpoise especially well-suited to monitoring by acoustic means.

***Methodology**:* Placement of multiple SAM units at both control and impact sites, in such a way as to allow for calculation of the effect of distance from the impact (construction at the turbine site and, eventually, the turbine itself). The SAM data can also provide habitat use indices (e.g. Detection-Positive Minutes per hour) which can be used in statistical analyses as abundance data would be, thus allowing for a beyond-BACI analysis. Environmental impact assessments in Danish and German waters have used various numbers and layouts of T-PODs (the predecessor to the C-POD) depending on the site and resources available (Leeney and Tregenza, 2006).

Replicate units (allowing for both replication and for back-up in case of unit malfunction) should be placed at increasing distance increments from the turbines to examine the impact range. As some studies have documented an effect of pile driving on cetaceans beyond 21 km from the source, it is recommended that SAM units are placed at distances of between 2 and 5 km out to a distance of at least 30 km. The same deployment structure should be in place at control site(s).

***Equipment**:* C-PODs (www.chelonia.co.uk) or a similar technology (Aquatec and Woods Hole Oceanographic Institute have produced similar monitoring tools).

Species-specific descriptive acoustic studies (Advised)

Several species which are likely to occur in the control and impact sites have not been studied before using C-PODs. Additionally, there are not good existing data on the echolocation characteristics of many species, such as the Atlantic white-sided dolphin (*Lagenorhychus acutus*). In order for the SAM effort to be most effective, supporting work is recommended to characterize the click characteristics of at least several species that are very likely to be encountered in the area, for which data on echolocation characteristics are deficient.

***Methodology**:* This will involve targeted vessel-based searches for specific species followed by acoustic sampling in the close vicinity of these species using a hydrophone with high sampling rates which can measure frequencies above 200 kHz. Collection of data on species, group size and behavior will accompany the acoustic sampling. These data will then inform how best to set the C-PODs for monitoring the area of interest and will also enable a more accurate analysis of the resulting SAM data.

***Equipment**:* Calibrated hydrophone, amplifier and sound card or oscilloscope.

Land-based Surveys for Stranded Pinnipeds (Recommended)

On the islands of Monomoy and Muskeget, regular (2-4 per month) searches for beached carcasses of seals should be carried out in every month of the year. Any carcasses should be extensively photographed and standard data collection for stranded pinnipeds should be carried out. Any animals displaying injuries which could be associated with turbine blade trauma should be removed for necropsy, if possible.

At-sea, Platform-based Observations (Advised)

The SeaGen turbine in Strangford Lough, Northern Ireland, is one of the world's first full-scale, operational tidal turbines (http://www.seageneration.co.uk/). It has been in place since 2008. The structure of this turbine, with a platform above water, is such that observations of the water directly surrounding the turbine could be made. Marine mammal observers have now been replaced by active sonar, which shuts down the turbine operation when any marine mammal is detected within a 50 m radius of the turbine (Bedford and Fortune, 2010). Such a setup, allowing for *in situ* observations of the occurrence of marine megavertebrates in close vicinity to the turbines, would be beneficial to understanding the effect these structures have on the Muskeget Channel environment. Platform observations would allow the collection of detailed data on occurrence and behavior of various species in the immediate vicinity of the turbines as well as direct confirmation of any immediately apparent negative or non-negative effects.

Underwater Imaging for Behavioral and Abundance Studies (Advised as trial methodology)

There remain several questions that will be difficult to address, such as the underwater response of diving birds as well as species such as basking sharks to submerged, moving turbine blades. Although the underwater environment is likely to be turbid, a trial of an underwater video camera affixed to one of the turbine bodies is recommended. For comparatively little effort, such a technique may provide a rare glimpse of the behaviors exhibited by certain species in close proximity to these structures.

> ***Equipment**:* A camera such as the DeepSea Power & Light Multi SeaCam 1060. Video capturing device and power supply also required.

An alternative method that shows promise is **sonar imaging**. A multi-beam imaging sonar, such as **Dual-Frequency Identification Sonar (DIDSON)** has already been proposed as part of the draft fisheries study plan for the site and, if incorporated into the study plan, will be deployed on one of the turbine structures to record information on fish behavior and direct impacts from the tidal turbines. Such technology is able to produce images of targets that pass through its sonar field-of-view.

The DIDSON produces a near-video quality that allows observation of underwater behaviors of various species in turbid and nighttime conditions. Although not established as a technique for surveying marine megavertebrates, a sonar imaging system has been used with some success at the Strangford Lough tidal turbine (Bedford and Fortune, 2010). Since small fish species can be detected with this technique, it is likely to work for larger animals as well.

> ***Equipment**:* The DIDSON Long Range model maximizes the amount of observable area in front of and behind the module. This model has an approximately 29° beam width and a 14° beam elevation. http://www.soundmetrics.com/

These monitoring elements are summarized in Table 4, along with target species for each method, recommended sampling frequency, duration of the sampling and any notes regarding safety or other considerations.

2.3 Mitigation

In their guidelines for minimizing the risk of disturbance and injury to marine mammals from pile driving (2009), the U.K.'s Joint Nature Conservation Committee (JNCC) notes that the "soft-start" procedure and protocols for piling operations (not proposed for use in this project) required for the protection of marine mammals may also be appropriate for marine turtles and basking sharks. In the U.K., JNCC now recommends, but does not yet require, the use of Acoustic Deterrent Devices (ADDs, also known as Acoustic Mitigation Devices, AMDs) to clear an area of marine mammals prior to a soft-start process for pile driving or blasting (JNCC, 2009).

In theory, ADDs have the potential to reduce the risk of injury to marine mammals and are relatively cost effective. Their use would be in conjunction with visual and/or acoustic monitoring. ADDs have been used in Denmark and at other European wind farm construction sites (e.g. Edrén *et al.,* 2010). However, evidence relating to the efficacy of such acoustic deterrents is limited and likely varies considerably among species (e.g. Berrow *et al.,* 2009; Leeney *et al.,* 2007; Cox *et al.,* 2003; Johnston, 2002); habituation is also likely after some time. Kastelein *et al.* (2010) reported considerable differences in detection distances of AMDs depending on the model of AMD, background noise levels and propagation conditions in the marine environment. If these devices are considered, the potential effectiveness of candidate devices on the key marine mammal species likely to be present in the area should be assessed as part of the environmental impact assessment process for the proposed activity.

Equipment*:* ADDs are available from a number of different suppliers such as Fumunda (http://pleskunasdesign.com/pages/specs.html), Aquatec (http://www.aquatecgroup.com/aquamark.html) and Dukane (http://www.dukane.com/seacom/default.htm

Table 2: Summary of Advised Monitoring Program Elements

Method	Target	Sampling frequency	Duration	Comments
Aerial surveys	All megavertebrates	2 per month (minimum), per site	Two years prior to turbine installation through operation	• Communicate with local aerial survey teams • Safety protocol & equipment required
Strandings surveys	Seals	2-4 per month, per site (Monomoy & Muskeget)	During turbine installation & at least first year of operation	
Static Acoustic Monitoring (1)	Odontocetes	Continuous at 3 sites	Two years prior to turbine installation and through operation	• SAM costs may require choice of one/ other technique. What are priority species?
Static Acoustic Monitoring (2)	My (& Od, depending on system employed)	Continuous at 3 sites	Two years prior to turbine installation and through operation	
Seascape acoustic mapping	Background noise	Minimum 3 replicate samples per year, over spring tides, in each project phase, at each site	Two years prior to turbine installation and through operation	• Safety protocol required for boat-based work during strong tides
Species-specific acoustic sampling	Odontocetes	Intensive period of 2-3 weeks prior to commencement of SAM likely to suffice for key species	One month	• Identification of data-deficient species required
Platform-based monitoring	All megavertebrates	Regular 3-4 h samples at least once per week	Two years prior to turbine installation and during turbine operation	• Likely only possible at impact site
Sonar detection	All megavertebrates (especially targeted at Se, Od, My & CM)	Continuous; initially carried out simultaneously with platform-based observations	Two years prior to turbine installation and during turbine operation	• Further investigation required – does this require on-site shut-down capacity? • Likely only possible at impact site
Video/ Sonar imaging	All megavertebrates (esp. Se, Av & CM)	Trial period over 3-4 weeks at start of project	If successful, short periods of monitoring (e.g. 24 h per week) in each phase of project	• Only practical at impact site

Species groups codes: Od – Odonotcetes; My – Mysticetes; CM – basking shark; Tu – turtles;
Se – seals; MM – sunfish; Av – birds.

(1) Using C-PODs or another method for detecting odontocetes.
(2) SAM for Mysticetes – will require greater investment in equipment and considerable additional data processing time

4 References


Photo: E. Bradfield

Literature Cited – Methods

Akamatsu, T., Teilmann, J., Miller, L.A., Tougaard, J., Dietz, R., Wang, D., Wang, K., Siebert, U. and Naito, Y. 2007: Comparison of echolocation behavior between coastal and riverine porpoises. Deep-Sea Res. 54: 290-297.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behavior 49: 227-267.

Bedford, G. and Fortune, F. 2010. SeaGen Biannual EMP update. 21 April 2010. Report ref. 9S8562/R/303719/Edin, 31 pp. Retrieved from http://www.seageneration.co.uk/downloads/SeaGen%20biannual%20report%20April%202010.PDF.

Berrow, S., Cosgrove, R., Leeney, R.H., O'Brien, J., McGrath, D., Dalgard, J. and LeGall, Y. 2008. Effects of acoustic deterrents on the behavior of common dolphins (*Delphinus delphis*). Journal of Cetacean Research and Management 10: 227-233.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. 2001. Introduction to Distance Sampling. Estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Campana, S.E., Gibson, J., Brazner, J., Marks, L., Joyce, W., Gosselin J.F., Kenney, R. D., Shelton, P., Simpson, M. and Lawson, J. 2008. Status of Basking Sharks in Atlantic Canada. Canadian Science Advisory Secretariat Research Document 2008/004. 67 pp.

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

Clark, C.W., Brown, M.W. and Corkeron, P. 2010. Visual and acoustic surveys for North Atlantic right whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts, 2001–2005: Management implications. Marine Mammal Science DOI: 10.1111/j.1748-7692.2010.00376.x.

Cox, T.M., Read, A.J., Swanner, D., Urian, K. and Waples, D. 2003. Behavioral responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. Biological Conservation 115: 203-212.

Cronin, M.A., Duck, C.D. and O'Cadhla, O. 2006. Aerial surveying of grey seal breeding colonies on the Blasket Islands, Co. Kerry, the Inishkea Group, Co. Mayo and the Donegal Coast, Ireland. Journal for Nature Conservation 15: 73-83.

Diederichs, A., Nehls, G., Dähne, M., Adler, S., Koschinski, S. and Verfuß, U. 2008. Methodologies for measuring and assessing potential changes in marine mammal behavior, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. BioConsult SH report to COWRIE Ltd. 91 pp. Retrieved from http://www.offshorewindfarms.co.uk/Assets/CHANGE0607%20Final%20version%20 2010.pdf.

Diederichs, A. Hennig, V. and Nehls, G. 2008. Investigations of the bird collision risk and the responses of harbor porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark. Part II: Harbor porpoises. Final Report. 96 pp.

Edrén, S.M., Andersen, S.M., Teilmann, J., Carstensen, J., Harders, P.B., Dietz, R. and Miller, L.A. 2010. The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. Marine Mammal Science 26 (3): 614-634.

EMEC (European Marine Energy Centre). 2008. Environmental Impact Assessment (EIA) guidance for developers at the European Marine Energy Centre. 22 pp. Retrieved from http://www.emec.org.uk/pdf/EMEC%20 EIA%20Guidelines%20GUIDE003-01-03%2020081106.pdf.

Garthe, S. and Huppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41: 724-734.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. and Øien, N. 2002. Abundance of harbor porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39: 361-376.

Hays, G.C., Farquhar, M.R., Luschi, P., Teo, S.L.H. and Thys, T.M. 2009. Vertical niche overlap by two ocean giants with similar diets: oceanic sunfish and leatherback turtles. Journal of Experimental Marine Biololgy and Ecology 370:134–143. doi:10.1016/j.jembe.2008.12.009.

Houghton, J.D.R., Doyle, T.K., Davenport, J. and Hays, G.C., 2006. The ocean sunfish *Mola mola*: insights into distribution, abundance and behavior in the Irish Sea and Celtic Seas. Journal of the Marine Biological Association of the United Kingdom 86, 1237-1243.

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

Jean, C., Ciccione, S., Ballorain, K., Georges, J.-Y. and Bourjea, J. 2010. Ultralight aircraft surveys reveal marine turtle population increases along the west coast of Reunion Island. Oryx 44: 223-229.

Johnston, D.W. 2002. The effect of acoustic harassment devices on harbor porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. Biological Conservation 108 (1): 113-118.

Joint Nature Conservation Committee. 2009. Annex B - Statutory nature conservation agency protocol for minimising the risk of disturbance and injury to marine mammals from piling noise. Retrieved from https://www.og.decc.gov.uk/environment/jncc_pprotocol.pdf.

Kastelein, R.A., Hoek, L., Jennings, N., de Jong, C.A.F., Terhune, J.M. and Dieleman, M. 2010. Acoustic mitigation devices (AMDs) to deter marine mammals from pile driving areas at sea: Audibility and behavioral response of a harbor porpoise and harbor seals. COWRIE Ref: SEAMAMD-09, Technical Report 31st July 2010. Retrieved from http://www.offshorewindfarms.co.uk/Assets/Final%20report%20COWRIE%20Ref%20 SEAMAMD-09.pdf.

Langston, R.H.W. and Pullan, J.D. 2003. Windfarms and birds: an analysis of windfarms on birds, and guidance on environmental assessment criteria and site selection issues. RSPB/BirdLife International Report to the Council of Europe (Bern Convention). T-PVS/Inf (2003) 12.

Leeney, R.H., Berrow, S., McGrath, D., O'Brien, J., Cosgrove, R. and Godley, B.J. 2007. Effects of pingers on the behavior of bottlenose dolphins. Journal of the Marine Biological Association, UK 87: 129-133.

Leeney, R.H., Broderick, A.C., Mills, C., Sayer, S., Witt, M.J. and Godley, B.J. 2010. Abundance, distribution and haul-out behavior of grey seals (*Halichoerus grypus*) in Cornwall and the Isles of Scilly, UK. Journal of the Marine Biological Association of the UK. Published online, June 2010.

Leeney, R.H., Broderick, A.C., Witt, M.J., Richardson, P.B., Jarvis, D.S., Buchanan, J. and Godley, B.J. (In review) Marine megavertebrates of Cornwall and the Isles of Scilly: relative abundance and distribution.

Leeney, R.H. and Chronic, J. 2010. PCCS Right Whale Aerial Survey Program Safety Policy and Operating Procedures Manual. Produced for the Provincetown Center for Coastal Studies. 28 pp.

Leeney, R.H., Stamieszkin, K., Mayo, C.A. and Marx, M. 2009. Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters - 2009. Report to DMF. Provincetown Center for Coastal Studies, USA.

Leeney, R.H., Stamieszkin, K., Jaquet, N., Mayo, C.A., Osterberg, D. and Marx, M. 2008. Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters – 2008. Report to DMF. Provincetown Center for Coastal Studies, USA.

Leeney, R.H. and Tregenza, N.J.C. (Eds) 2006. Proceedings of the workshop: Static Acoustic Monitoring of Cetaceans, held at the 20th Annual Meeting of the European Cetacean Society, Gdynia, Poland, 2nd April 2006. ECS Newsletter 46 – Special Issue, July 2006. Retrieved from http://www.seaturtle.org/mtrg/personnel/SAM_report.shtml.

Marsh, H. and Saalfeld, W.K. 1989. Aerial Surveys of Sea Turtles in the Northern Great Barrier Reef Marine Park. Australian Wildlife Research 16: 239-49.

Matthiopoulos, J., McConnell, B., Duck, C. and Fedak, M. 2004. Using satellite telemetry and aerial counts to estimate space use by grey seals around the British Isles. Journal of Applied Ecology 41: 476-491.

Palka, D. 1995. Effects of Beaufort sea state on the sightability of harbor porpoises in the Gulf of Maine. Report to the International Whaling Commission SC/47/SM26.

Pearce-Higgins, J.W., Stephen, L., Langston, R.H.W. and Bright, J.A. 2008. Assessing the cumulative impacts of wind farms on peatland birds: a case study of golden plover *Pluvialis apricaria* in Scotland. Mires & Peat 4: 1-13. Retrieved from http://www.mires-and-peat.net/map04/map_04_01.pdf.

Philpott, E., Englund, A., Ingram, S. and Rogan, E. 2007. Using T-pods to the echolocation of coastal bottlenose dolphins. Journal of the Marine Biological Association 87: 11-17.

Pomeroy, P.P., Redman, P.R., Ruddell, S.J.S., Duck, C.D. and Twiss, S.D. 2005. Breeding site choice fails to explain interannual associations of female grey seals. Behavioral Ecology and Sociobiology 57: 546-556. doi 10.1007/s00265-004-0882-6.

Sims, D.W., Queiroz, N., Doyle, T.K., Houghton, J.D.R. and Hays, G.C. 2009. Satellite tracking of the world's largest bony fish, the ocean sunfish (*Mola mola*) in the North East Atlantic. Journal of Experimental Marine Biology and Ecology 370: 127-133. doi:10.1016/ j.jembe.2008.12.011.

Sims, D.W., Southall, E.J., Tarling, G.A. and Metcalfe, J.D. 2005. Habitat-specific normal and reverse diel vertical migration in the plankton-feeding basking shark. Journal of Animal Ecology 74: 755-761.

Teilmann, J. 1995. Influence of seastate on abundance estimates of harbor porpoise (*Phocoena phocoena*). Report to the International Whaling Commission SC/47/SM45.

Teilmann, J., Henriksen, O.D., Cartensen, J. and Skov, H. 2002. Monitoring effects of offshore windfarms on harbor porpoises using PODs (porpoise detectors). Ministry of the Environment, Denmark. 95 pp.

Thompson, P.M., Lusseau, D., Barton, T., Simmons, D., Rusin, J. and Bailey, H. 2010. Assessing the responses of coastal cetaceans to the construction of offshore wind turbines. Marine Pollution Bulletin 60: 1200-1208.

Tougaard, J., Carstensen, J., Henriksen, O.D., Teilmann, J. and Hansen, J.R. 2004. Harbor porpoises on Horns Reef – effects of the Horns Reef wind farm. National Environmental Research Institute, Roskilde, Denmark, 69 pp.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H. and Rasmussen, P. 2009. Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). Journal of the Acoustical Society of America 126 (1): 11-14.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. 4(1): 3-15.

Underwood, A.J. 1995. Ecological research and (and research into) environmental management. Ecol. Appl. 5(1): 232-247.

Wilson, B. Batty, R.S., Daunt, F. and Carter, C. 2007. Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland, PA37 1QA. 110 pp.

Marine Megavertebrates and Fishery Resources in the Nantucket Sound – Muskeget Channel Area